Naval Postgraduate School

New Student's Introduction to the Operations Research Department

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Introduction

Welcome to the Naval Postgraduate School and the Operations Research Department. As of January 2006, the OR Department is responsible for three curricula: Operations Analysis (OA or "360") and Joint Operational Logistics (JOL or "361") are both about two year long leading to the degree Master of Science in Operations Research (MS/OR). Human Systems Integration (HSI or "362") is a recent addition to the Department's offerings. The study of "Human Factors" has been a discipline within Operations Research since its inception. Changes to Department of Defense acquisition policy and the increasing need to place the human operator at the center of an incredibly complex system led to the formal establishment of Human Systems Integration Curriculum in the summer 2004. This program also lasts about two years and leads to a Master of Science in Human Systems Integration.

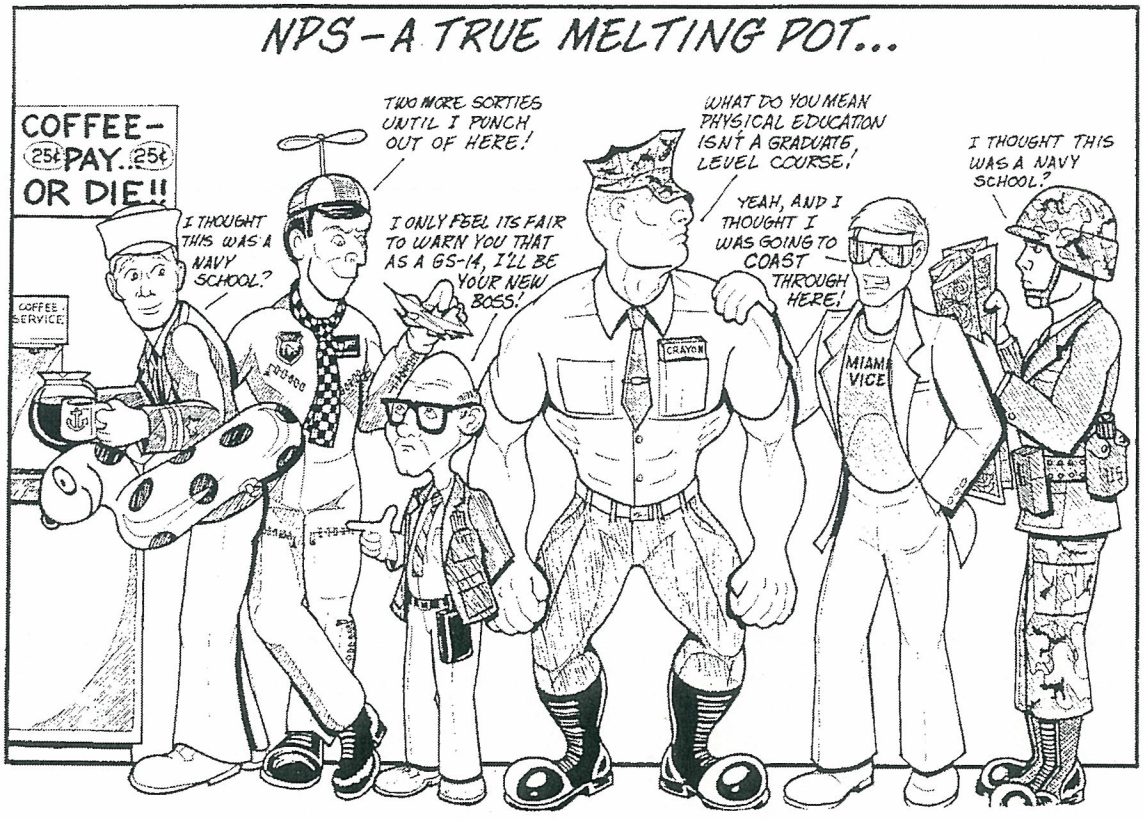
Take note of the "about" qualifier in the descriptions of curricula length in the preceding paragraph. Some of you have arrived early to attend a quarter or two of "Refresher" to refine mathematics knowledge and study skills. Still others will be required by their warfare communities to integrate Phase I of Joint Professional Military Education (JPME) into their programs, adding a quarter to your stay. Though you and your cohort (students starting together) are working through a standard set of course matrices, it's not quite a lock-step process.

The Operations Research Department's programs have their foundation in the Operations Analysis curriculum. The Navy established the curriculum in 1951 when it recognized that the OR techniques pioneered in WWII were worth preserving, and has maintained it ever since. The OR Department at NPS is, at least as far as we can tell, the oldest in the nation. It remains on par with similar programs at MIT, Cal Berkley, Stanford, and other superb universities. You will be abundantly proud of your NPS OR Master's Degree. You will also work hard for it.

By now, as the cartoon[1] shows, all services and even an occasional DoD civilian can be found in attendance. NPS distinguishes between the OA curriculum, a course of study, and the OR department, a collection of faculty. The rest of the world makes less of a distinction between OA and OR, and uses terms such as Process Engineering, Systems Engineering Management Sciences, and Systems Analysis to include many of the same tools. Whatever the name, the matter at hand is applying systematic, quantitative analysis to assist decision makers; whether those decision makers be involved in planning a military operation, a military services procurement program, or optimizing the arrival and departure of components in a manufacturing process.

[1] This cartoon, and the Ratman cartoons throughout, were drawn by Gus Stafford, a 1990 OA alumnus

The Navy sponsor for the Operations Analysis curriculum is the Director of the Assessment Division (N81). Navy graduates may spend a tour there, or in one of many other billets that are coded to require the 3211 (OA) or 3212 (JOL) sub-specialty codes. Other services have similar coding systems; as an example, your U.S. Army colleague may consider himself a member of the Function Area 49 community (FA49). Similarly, the Joint Operational Logistics Curriculum is sponsored by the Deputy Chief of Naval Operations for Material Readiness and Logistics (N4). As of December 2004 the decision is pending, but the Human Systems Integration curriculum's sponsor is likely to be the Deputy Chief of Naval Operations for Manpower and Personnel (N1). As was the case in Operations Analysis, there are strong ties between Navy curriculum sponsors and the managers of officer communities with similar skills in the other services. We think that the techniques and attitudes that you will learn here will prove to be of practical and intellectual value to you throughout your career and life, whatever your service and whether you are serving in a coded billet or not.



On account of the wide spectrum of interests found in the student body, the OR Department's curricula have developed several *options* that will be introduced in a following section. All lead to the same degree and the same P-code. You are advised to select an option early as some of the tracks require different classes early in the curriculum. You will also need to select some electives and usually an experience tour site. These choices should be made under the guidance of

the OR Department's Program Officer, the professor with whom you are most interested in working, and the OA, JOL, or HSI Academic Associates (as appropriate). The latter two are faculty who are usually in the OR department. The academic associate and the curricular officer function as a team that is responsible for the general welfare of the OA/JOL/HSI curriculum, taking account of guidance from the sponsor and feedback from you. Take advantage of the presence of these advisors, particularly (once you have selected an option) the option advisor.

The majority of you are experienced officers of U.S. military services, studying for a Master's Degree to consolidate your skills following years of training and significant operational tours. There are, however, several other significant elements of the OR Department's student population; you are, indeed, a diverse group.

About four to six Ensigns are sent to NPS to earn Masters Degrees in one year. These are truly the best and the brightest out of any given year group, the top graduates from both the U.S. Naval Academy and NROTC Units. They are participants in the "Immediate Graduate Education Program," and, if history is any indicator at all, we will call them collectively "IGEPs." In general, the Navy Lieutenants and Marine Corps Captains offer real-world operational knowledge, while the IGEPs can complete a double integral in spherical coordinates. The more senior officers would do well to seek academic partnerships with the IGEPs.

NPS also has two international partnerships providing students to the OR Department's student population.

The Korean National Defense University sends several students each year for a four quarter program leading to an NPS MSOR. These particular students have completed courses in calculus, probability, statistics, linear algebra, and object-oriented computer programming languages before they arrive. Their English skills can be a challenge for them, but their mathematics and skills in abstract thought have them well prepared for the advanced topics in Operations Analysis.

NPS also has a cooperative program with the Temasek Defense Systems Institute (TDSI) at the National University of Singapore (NUS). Several well-qualified U.S. students travel to Singapore for two quarters, joining a cohort of NUS students, generally civilians from Singapore's Ministry of Defense.

Most of the classes that you attend will have identifying numbers that begin with the two letters OA, which means that the course is the responsibility of the OR Department. (As an aside, the OR Department is also responsible for OS classes which are taught to students in other academic disciplines.) In the early quarters you will also find some courses from other departments (MA identifier for Math Department Classes or GB for courses offered by the Graduate School

of Business and Public Policy (GSBPP)). Early in your program, most of the students in your classroom, your "cohort" will be in either the OA or JOL curricula, but HSI students are on a unique track from the start. As your program continues, your cohort will divide along lines tied primarily to individual student research interests. "Optimizers" will go one route, while "Data Analysts" or "Simulators" will go another.

Student Life

Welcome to the world of technology. The personal computer, intranet, and broad use of "distributed learning" technologies may come as quite a shock to you if you've been out of the academic arena for more than about four or five years. It certainly came as a shock to one of the authors of this guidebook who left NPS in 1985 when the single main-frame campus computer was located on the first floor of Ingersoll Hall. While a student at NPS you will be required to use several different e-tools every day; most of which will be new and some of which will might even be helpful.

Student Services Web Page

The Student Services office maintains a web page on the NPS intranet. This web page is the portal to all other services offered at NPS. In this web page you will find links to Military Community Information, thesis information, leave/travel policy, and academic information, and many others. The link is http://www.nps.edu/CurStudents/index.html

Some items on this website are:

- Daily Check-In
- Current Announcements
- Student Information Handbook

The Daily Check-In is at the top of the Quick Links panel on the right side of the web page. This is where you will also go to perform your DAILY electronic muster. While at NPS you are required to muster electronically Monday through Friday. The only exceptions are school holidays and days in which you have approved TAD or Leave requests (there is, of course, an on-line form – follow the links). You may download a Cisco VPN client application provided on the Information Technology web page that will allow you to check-in and read your NPS email through a dial-up connection from home. (See http://www.nps.edu/Technology/index.aspx.) **Failing to muster electronically is among the fastest ways to gain the attention of the Dean of Students and the Student Services Officer:** this is a bad thing.

Current Announcements is the top item in the center panel of the web page. Reading the daily announcements should be part of your daily routine. Recognizing that all students reading this page are not Navy officers, a brief sidebar is appropriate. Parts of a ship's morning routine are "Officers' Call" and "Quarters for Muster, Instruction and Inspection." Even in this ever faster e-world, sailors still muster with their Division and listen to the Chief and Division Officer "get the word out." Well, Current Announcements is NPS's e-equivalent. Reading "the gouge," and being in the right place at the right time in the correct uniform is another good way to escape the notice of the Dean of Students and Student Services Officer.

The Student Information Handbook is available online and is a "must read." You will notice it about half-way down the Quick Links panel on the right of the daily check in page. In it you will find the answers to all of your personal and professional academic needs.

Python

PYTHON is a program that tracks every student's personal and academic information. A link to Python can be found on the Quick Links panel on the Current Students web page. In Python you will find your curriculum matrix and grades. Python records your transcript, helps us monitor your progress, and manages the "drop/add" process for tailoring your particular schedule. You will make all academic requests for curricular changes (e.g. review the student course catalog, adding or dropping a class, requesting a segment switch, requesting course electives, etc.) via Python. The Operations Research Department's Education Technician (Ms. Lisa Puzon in Glasgow Hall Room 220B) is your ally is using Python. There are specific windows of time in which your interaction with Python is critical. As an example, about the second or third week of a current quarter, you will be notified "Current Announcement" (see the paragraph above) to input NEXT quarter's schedule into Python. Why so early? Think about it: Python drives the academic machine: academic departments' Chairs for Instruction assign instructors to courses, the facilities folks allocate classrooms, and the Navy Exchange orders the text books. Python is important. In addition to updating your curriculum matrix, Python must be kept updated with personal and family information.

Every quarter you are required to submit a Student Opinion Form (SOF) for each class that you took. This is done in Python as well. A SOF must be completed before you can see the grade earned in a specific class. SOFs are very important; this is the avenue in which the student provides constructive criticism and recommendations for both the course as a whole and the specific instructor(s) for the class. The Department Chair reviews every SOF submitted for his professors. SOFs are the basis for instructor evaluations, tenure recommendations, as well as course changes. Read that sentence again: SOFs

are a critical element in salary and tenure negotiations. You will find your instructors, by and large, keenly interested in delivering a quality product to their customers – YOU!

Blackboard

Blackboard is the name of a software suite used by several universities to enhance both classroom teaching and distance learning. It is used extensively at NPS and a link to Blackboard can be found on the Quick Links panel on the Current Students web page. The majority of NPS professors use the NPS Blackboard site to post course material such as lecture notes, presentations, grades, etc. Some even require weekly participation in course related chat rooms and administer quizzes and tests on their course using the site. Blackboard is outside of the NPS firewall so it is accessible from anywhere (i.e., home PC). There are plenty of opportunities to learn Blackboard, including one-hour orientation courses. Take advantage of them. It is not a difficult software suite, but as is often the case an hour of formal instruction can save ten hours of frustration.

The Dudley Knox Library

There are still shelves of books available at the library, but increasingly important is the access through the library to huge data repositories. Orientation tours are regularly available; the "Current Announcements" section of the electronic check-in will provide details. The Library is an incredible resource, vastly misunderstood by the many students at NPS. Resources are focused on making it a world-class research facility. You would do yourself a grave disservice if you did not become familiar with what's available, both on the shelves and electronically directly to your desktop.

Graduation Requirements

NPS has the usual A, B, C, grading system, with an A being 4 points and subsequent letters decreasing by 1. Throughout your tenure at NPS, the registrar will compute and report to your advisors various statistics concerning your performance to date. The most important of these is GQPR, the average grade obtained in all "graduate" courses (courses whose identifier numbers start with either 3 or 4 and which are not pass/fail). GQPR must exceed 3.0 (a B average) if you are to be awarded any MS degree at NPS. There are also some other grade point requirements, but it is hard to flunk them while passing the GQPR test.

Let's get down to some brass tacks. The first four quarters are the toughest; perhaps the toughest on campus. The fact is that OA, JOL, and HSI curricular loads tend to lighten after the experience tour. In general, students get higher grades in 4000 level courses than in lower level courses. GQPR gradually increases as you proceed through the curriculum. A GQPR of 2.9 after three quarters is therefore cause for concern rather than despair. Address the concern head-on through consultation with your curricula's Academic Associate and the OR Department's Program Officer. A small fraction of those who complete the OA curriculum do not get the MS/OR degree. Among those who do not, the most common reason is GQPR less than 3.0. The next most common is failure to finish a thesis.

An informal guide handed out the first week of your experience at NPS may seem too early for thesis advice, but here it is: Do not, under any but the most extraordinary circumstances, consider leaving the University with your thesis incomplete. In my role as OR Department Program Officer each quarter I get about a handful of formal requests for second and third one-year extensions. Make up your mind RIGHT NOW: "I am going to get my thesis done while a student in residence at NPS!"

There are also some requirements concerning the courses taken. You are unlikely to get into trouble on this score, but still it is worth recording the two most important of these requirements: NPS requires that you have at least 32-quarter hours of graduate (3000 or 4000 level) courses, plus a thesis, and the OR department requires at least 18-quarter hours of 4000 level OA courses. The quarter hours for each course are stated in the catalog and in the option matrices at the end of this pamphlet. A 3-1 course counts for 3.5 quarter hours because the second "lab" component is given only half the weight of the first "lecture" component. The Academic Associate for your particular curricula (OA, JOL, or HSI) is your best source of advice on these requirements. A complete list of all graduation requirements, including those mentioned above can be found in the Academic Council Policy Manual, available from the NPS home page.

The Curricula

You are completing two distinct sets of requirements as you complete your course work and thesis in the OA, JOL, and HSI curricula. The Educational Skill Requirements (ESRs) are those skills mandated by the Navy sponsors of the respective curricula. The Navy sponsors do cooperate with the other services and DoD to ensure ESRs meet the future needs for officers with specific sub-specialties. Additionally, NPS is an accredited university and, as such, there are specific requirements mandated to satisfy requirements for a Master of Science degree. ESRs and general course matrices are provided by Appendix A.

OA Options

There are different OA options, "tracks," and you will become increasingly familiar with them as your time here continues. The tracks available will evolve over your time here at NPS, so the details are better left for discussions with academic advisors about the third quarter. But for right now:

- Modeling, Simulation, and Analysis (open to all);
- Joint and Land Combat (required for Army Officers);
- Marine Corps (required for Marine Corps Officers);
- Supply Corps (an OA track for Supply Corps Officers distinct from JOL); and
- International (Required for all International Students).

are shown at the end of this pamphlet in matrix format. Each row represents an academic quarter and the cell entries are the required courses for that quarter. Each track has one quarter split into two parts. This is because that quarter is your experience tour quarter. The first six weeks are a compressed academic session (double time); the remaining six weeks are set aside for the student to go on an experience tour (Travel!) for thesis research.

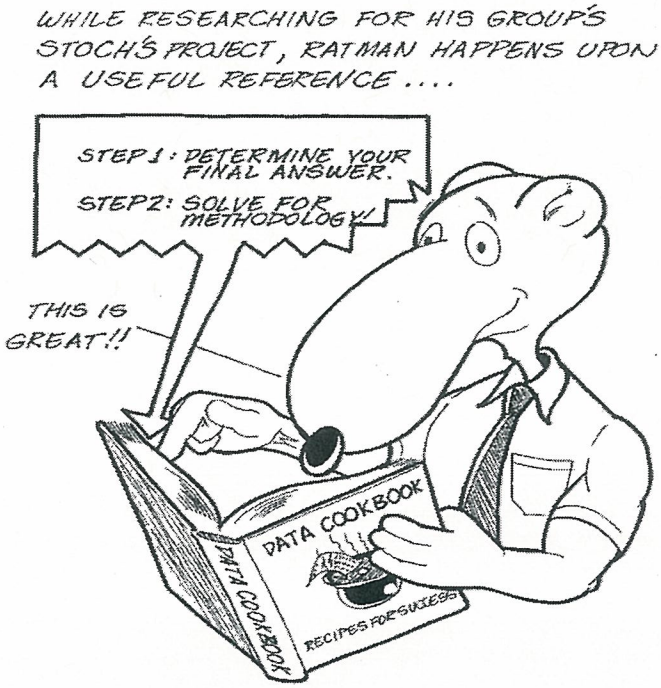
The Core

OA and JOL differ little from each other up until the experience tour, so it is reasonable to refer to the courses up until then as a common "core". OR is a quantitative discipline, and the core is designed to introduce the required ideas, tools, and software.

- The OA3101, OA3102, OA3103 sequence is devoted to the mathematics of uncertainty: probability, statistics, and data analysis. OA3304 (Decision Theory) and OA3301 (Stochastic Process Modeling) are the "capstone courses" of this sequence.
- The computation and simulation sequence evolves, but as of this writing consists of OA2200 and OA3200 (JAVA and more JAVA), then a Simulation course (OA3302) during which you will find the use of programming language will become an invaluable asset in creating a broad range of simulation tools. This work is exciting and includes state-of-the-art visualization and mathematical modeling techniques.
- The OA3201, OA4201, OA4202 sequence introduces optimization, beginning with linear programming in OA3201 and progressing to various generalizations and special cases in the other two. Network OA4202 is a "fire-hose" course; you will take it for two hours in the first half of your experience tour quarter. It's a challenge, but is consistently praised by graduates.

- OA3602 (Search Theory and Detection), OA4655 (Joint Combat Modeling), OA4801 (Spreadsheet Analysis) introduce a broad range of topics and* techniques useful for modeling and simulating combat.

By the time you leave for your experience tour, you should be ready for real-world problems.



Electives

Every option of the OA curriculum has at least one elective in it. Electives are usually OA-4xxx courses, but you may also consider courses taught by other departments. The objective should be to round out your education, to go more deeply into some subject that interests you, or to learn something that supports your thesis.

There are some constraints. Elective choices must be approved by your advisors, for one thing, and even with everyone's approval, you can't take a course if it isn't offered. Course scheduling in the OR department is done by the Associate Chairman for Instruction, who has a budgetary limit that essentially determines the number of sections that can be offered in a given year. In approximately August, he receives a demand forecast for the next fiscal year and makes a tentative teaching plan. NPS collects this information and in November releases the aptly labeled "tentative course schedule" for the rest of the academic year. It usually doesn't change much from year to year. This schedule is worth looking at if you are wondering what electives to take, but

remember that it is only tentative. Courses are taught in accordance with what demand actually turns out to be, which can differ a lot from the forecast, particularly late in the fiscal year. Often instructors will develop a new interesting and relevant course and request students who might find it useful to sign up for the class. What this means to you is that you can influence the electives that are actually taught by signing up for them as early as possible, and by convincing your classmates to do likewise. Roughly speaking, electives get taught in the same order as they get voted for, provided the votes come in early enough to permit faculty to plan their lives.

The OR Department

Most of the courses that you take will be taught by one of the approximately 42 faculty in the OR department. This same faculty is also likely to be involved as either advisors or second readers when you write your thesis. Most faculty are civilians with PhDs in a variety of areas, but there are also several military instructors. The easiest way to find out about the faculty is by browsing the department's home page, where you will find information about background, interests, publications, and thesis advising. If you find someone whose interests appear to overlap with your own, stop by and introduce yourself.

In case you are curious, life for a civilian faculty member usually consists of alternating quarters of research and teaching, with thesis advising and other academic duties going on continuously. Research is funded by the usual mechanism of writing proposals and hoping that they are funded. The NPS contract is for 10 months, but most faculty extend it to 12 months with funded research. All of this requires a certain amount of planning ahead, which partly explains why we are not as flexible with regard to offering electives as we would like to be. There are lots of subtleties here, and you may or may not ever fully understand the distinction between an "Associate Professor" and a "Research Assistant Professor."

What is critically important is that you recognize your role in the "Reimbursable Research" engine. As explained above, about half a civilian faculty member's living is made by delivering specific research products to clients, primarily within DoD, who pay for those products. Under the best of circumstances, your thesis research is part of that process. Under the guidance of your thesis advisor, you "chew" on a particular piece of the puzzle. Other students, the professor, and, rarely, expertise brought in from outside NPS, "chew" on other pieces of the puzzle. Over a period of two to three years, the picture emerges from the puzzle. Significant theses are written and students get Masters Degrees, professors publish summaries of the group's collective efforts, the frontiers of knowledge are pushed out, and NPS maintains its standing as a world-class Defense-related research institute.

Professional Societies

The Institute of Management Science and the Operations Research Society of America were combined in 1995 to form INFORMS (neat, huh? they got OR and MS and everything right in there), the main US society for our profession. INFORMS publishes several journals, the most readable of which is *Interfaces.* You might wish to browse through a copy, and more specifically you might wish to browse through Volume 26 Number 5, which includes an article on the OA curriculum (provided as an! INFORMS also publishes a slick magazine *OR/MS Today.* This magazine and several other benefits are available by joining the society as a student for $21 per year. Application forms are available from the academic associate. INFORMS has a Military Applications Society (MAS) that you can select upon joining.

INFORMS and its captive society MAS are an entirely unclassified forum, which distinguishes it from the Military Operations Research Society (MORS). MORS meetings have classified sessions, and are usually held at military bases, occasionally NPS. MORS and MAS together publish the unclassified *PHALANX* newsletter, which comes free if you join INFORMS/MAS (it also comes free even if you don't, since the curricular office gets a supply to give away). MORS sponsors the quarterly Tisdale award for the best military OR thesis. The competition for this award occurs during your final quarter.

The original OR journal was *Operations Research*, which is still published by INFORMS. Other relevant journals are *Management Science*, *Naval Research Logistics* (Professor Rosenthal is the editor), *European Journal of Operations Research,* and the journals produced by several other countries. The NPS library subscribes to all of those named plus several others.

Experience Tours

The OR Department is somewhat unique in its continuing insistence on an experience tour. Ultimately, practitioners of OA, JOL, and HSI develop and apply mathematical models, statistical analysis, simulations, analytical reasoning, and common sense to improve the understanding of real-world problems. The goal of the experience tour is to get you out to see real-world problems.

The single most significant source of ideas about your experience tour is a professor who's captured your interest or a specific element of the "OR Toolkit" with which you develop some fascination. As was mentioned before, the most effective Masters Theses are those that contribute to answering an issue of importance to a research sponsor. Developing a one-on-one relationship with a specific faculty member is an important part of this process. By the fourth

quarter, you will have been exposed to enough of the "OR Toolkit" and enough faculty members to begin to narrow down on an area of interest for your thesis.

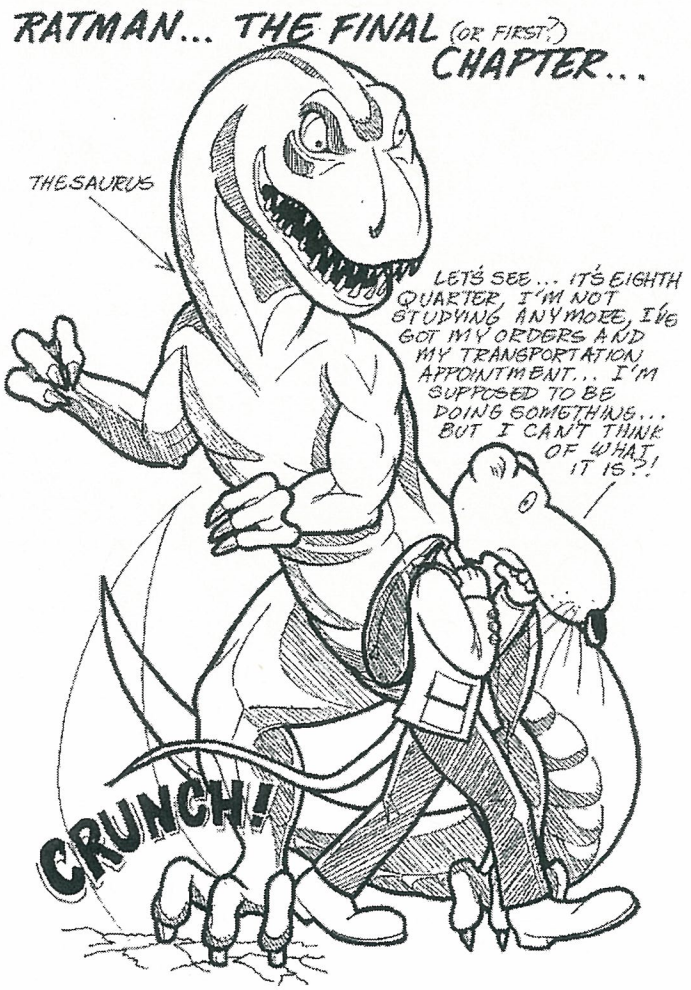
There are fall-backs. The curricular office keeps some loose-leaf notebooks that are worthwhile browsing before you choose an experience tour site. Those notebooks include some descriptions of opportunities, as well as feedback from your predecessors about how well their tours went. As you will see in browsing those notebooks, most tours are at DoD installations. Tours at commercial activities are possible, but of course care must be taken to prevent conflict of interest in that case. Additionally, organizations throughout DoD query both the OR Program Officer and the Chairman of the OR Department regarding the availability of a student to solve a particular problem. We keep lists; there are generally more issues than theses students to solve them.

In general, the professor with whom you are working on your thesis will have set aside resources to fund your experience tour. There are some exceptions, and the OR Program Officer can generally find resources for students who are working independently or have some unique requirements. There are also some other local sources of funds, but not enough to cover everybody. Hosts who are willing to pay are therefore greeted particularly warmly by the Program Officer. The amount of money involved is small in the grand scale of things, so most hosts are willing. There will be lots of discussion of this during the fourth quarter of the program. Do not think about this now; instead think about calculus and vector algebra.

Thesis

All OR curricula include thesis "slots" in the quarters following the experience tour. Most students say that the completion of a thesis requires more time than those three slots would seem to imply. Many schools have stopped requiring a thesis for the MSOR degree on account of the large time commitment on the part of both students and faculty. A thesis shall remain a critical requirement at NPS. *After* your thesis is complete, you will probably join most other alumni and faculty in defending it as having been worth the time and effort.

Many students find a thesis topic during the experience tour in the fifth quarter. However, it is not too early to begin thinking about what you are interested in focusing on for six or more months of your life. Remember that you are the one who selects the experience tour site, so knowing what you want will be an advantage when selecting a site and using your tour productively. Also, only about half of OR theses have anything to do with the experience tour -- in many cases the experience tour fails to produce a topic or may even discourage one. So, to avoid a visit by Ratman's "Thesaurus" monster, it is best to begin planning early.



The best source of thesis topics is your own experience. One of the beauties of OR is that our quantitative approach to decision making is applicable in such a wide variety of circumstances that there is likely to be something in your background that hasn't been analyzed quantitatively, but could be. Theses have been made out of the observations that a submarine has to decide what heading will minimize the chance of collision when coming to periscope depth, or that an LCAC must decide how much equipment to load from which mother ship in supporting an invasion, or that a particular change in personnel policy may or may not have resulted in jobs being performed better in a particular set of billets. All of these topics were chosen based on prior experience of the authors. In fact, one of the reasons why NPS can still afford to require a thesis is that NPS students like you are comparatively mature and experienced. Capitalize on that experience in selecting a topic.

The topics named above may sound overly simple, but they are not. "Chance of collision" begs to have a model of how collisions involving submarines and surface ships might occur. The LCAC is trying to do things fast, so it will shortly realize that the relationship between time and quantity in loading needs to be

well understood, and that it needs to understand what other LCACs are doing. How does one quantify "better performance" in a billet, and can the statistics be estimated from available data?

Considerations such as these can make a deceptively simple sounding problem turn out to be surprisingly complex. Any OR research topic has a tendency to grow, so the risk of selecting a problem that is trivial is much smaller than the risk of selecting a problem that is too big for the time available. An OR thesis is intended to be a scientific undertaking, so the details will take time. The devil (or worse yet Ratman's Thesaurus) is often found in those details. Start small.

The Program Officer keeps a compilation of thesis abstracts that will give you a good idea of the kind of OR theses that have been written in the past. A copy of each thesis can be found in the library, including theses that are classified.

Faculty members are the best source of thesis topics. If a lecture topic intrigues you or if you think the topic might be applicable to a thesis you have in mind, discuss it with the faculty member. Sponsors sometimes call faculty about problems that need to be solved. Ideally these calls will result in an entry in the catalog of prospective thesis problems that the curricular office keeps, but that system is not completely reliable. A direct approach to faculty can be useful.

Your thesis advisor is the most important faculty thesis contact. The thesis work is yours to do and yours to communicate, but the advisor is your consultant throughout. Every thesis must also have a second reader. The usual role for a second reader is basically quality control and making sure that the thesis is comprehensible by someone not intimately connected with the work, but the arrangement will depend on the faculty member that you select. As with your advisor, make sure that you understand what he expects and when he expects it. At least one of these two advisors must be an OR faculty member. If you have trouble finding appropriate faculty, talk to the academic associate. As soon as you have a topic and advisors lined up, fill out the Preliminary Report of Thesis form and get everybody to sign it.

NPS has a Thesis Manual that specifies standards for how a thesis must be written, and a thesis processing office to make sure that the standards are followed. The curricular office will make sure that you are aware of all the latest details. However, the most important rule for good writing is to first make sure that you have something to say. Before beginning your write-up, consult with your advisor as to whether you have reached that desirable state.

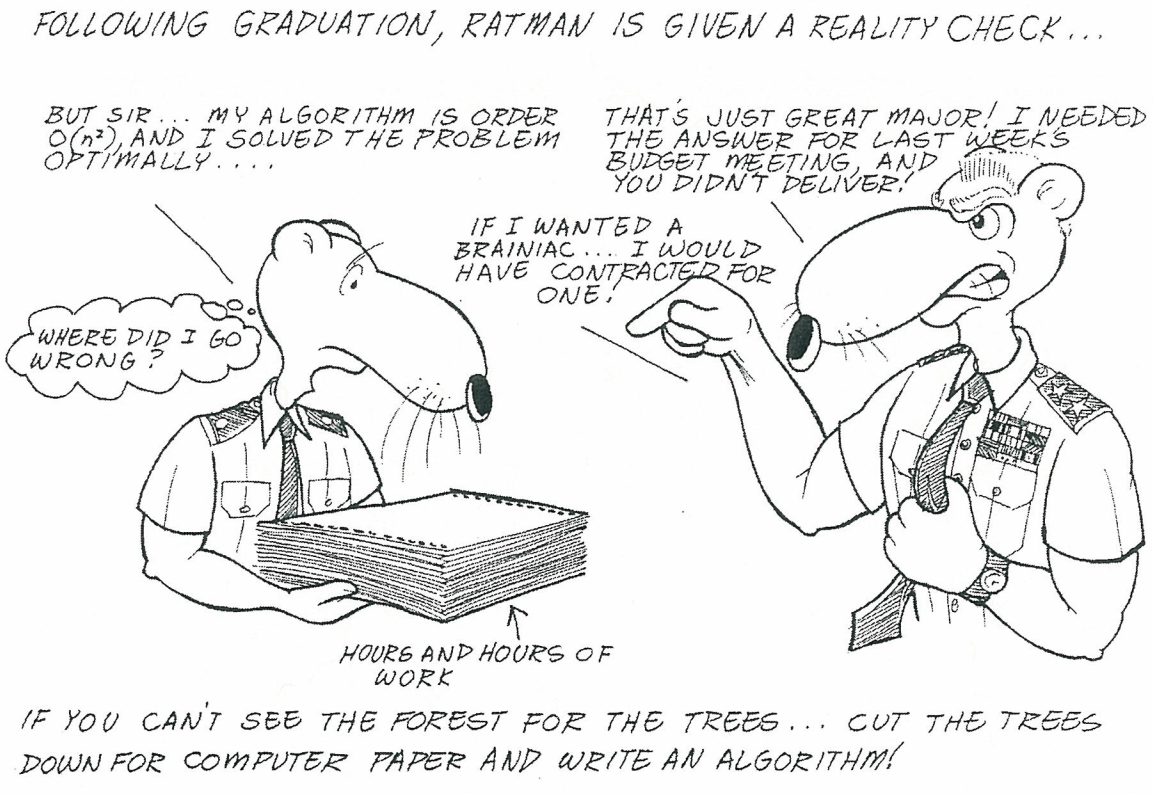
Joint Professional Military Education (JPME)

The Naval War College JPME sequence is built into each curriculum. Every NPS student must complete the Strategy and Policy course to graduate. The remaining courses were optional, but of late are becoming community

requirements. An NPS student who completes the entire Naval War College Non-Resident sequence (four courses) receives credit for JPME Phase I. As an example of the importance of JPME, consider the actions of Surface Warfare and Submarine communities' detailers. Officers are generally ordered to NPS for one quarter of refresher and seven quarters of OA or JOL. The eighth quarter is required (a total of nine) to enable JPME Phase I. The approval of this one-quarter PRD extension is largely *pro-forma*. JPME is becoming mandatory for various administrative and statutory boards. It is required by law for flag rank. The Naval War College also offers a Non-Resident Master's program. If you are interested, contact the War College faculty early as the course requirements is not very flexible.

After Graduation

It sometimes happens that an experience tour is undertaken by a student who has just barely passed (say) Nonlinear Programming. He or she is wondering how anybody can even comprehend all these techniques, let alone apply them, only to be pleasantly surprised at being able to do something that others regard as actually useful! The useful technique may simply be the ability to write a computer program or correctly interpret a probability analysis, rather than one of the more esoteric parts of OR.



The same thing often happens to recent graduates. A byproduct of mathematics and abstraction studied in OR is a certain comfort with making decisions using computers, models and numbers. This sophistication often leads to clarity of thinking that is valuable to decision makers and enviable to those without a similar education. The real goal of the NPS OR Department's curricula is to give you the opportunity to become sophisticated in that sense. If you can get there, you will be a more effective decision maker regardless whether you are serving in a subspecialty billet, or non-OR billet. For certain, the OA curriculum will enhance your opportunities in whatever you do after you leave the military. Your effectiveness will only occasionally take the form of a sophisticated analysis, but your approach to problems will still be constantly valued.

We like to get feedback from alumni. We occasionally even attempt a survey, although our surveys usually suffer from our inability to keep track of rapidly moving graduates. It is much easier for you to keep track of us, since the OA curriculum has been right here in Monterey since 1951. Please keep in touch.

APPENDIX A

Operations Analysis Naval Warfare Option w/ JPME

Note: May be tailored to meet unique requirements

Does not include a "Refresher" Quarter: Single Variable Calculus, Finite Math, and Vector Algebra

Q1	MA 3042 (4-0) Linear Algebra	MA 1115 (4-0) Multivariable Calculus	OA 3101 (4-1) Probability	OA 2200 (3-1) Computation I		OA 2900 (1-0) Workshop
Q2	OA 3304 (4-0) Decision Theory		OA 3102 (4-2) Statistics	OA 3200 (4-1) Computation II	NW 3230 (4-2) Strategy and Policy	OA 2900 (1-0) Workshop
Q3	OA 3401 (4-0) Human Performance	OA 3201 (4-0) Linear Programming	OA 3103 (4-1) Data Analysis	OA 3301 (4-0) Stoch Models I		OA 2900 (1-0) Workshop
Q4	OA 3602 (4-0) Search Theory and Detection	OA 4201 (4-0) Nonlinear Programming	OA 4655 (4-0) Joint Combat Modeling	OA 3302 (4-0) Simulation		OA 2900 (1-0) Workshop
Q5a		OA 4202 (4-0) Networks	OA 4801 (4-0) Spreadsheet Analysis			
Q5b	OA 3900 (5-0) Experience Tour					
Q6	OA 0810 (0-8) Thesis Research	OA 4XXX Course to Support Thesis[1]	OA 4602 (4-0) Joint Campaign Analysis		NW 3275 (4-0) Joint Maritime Operations	
Q7	OA 0810 (0-8) Thesis Research	OA 4XXX Course to Support Thesis[1]	OA 4604 (4-0) Wargaming Analysis		NW 3276 (2-2) Joint Maritime Operations	
Q8	OA 0810 (0-8) Thesis Research	XX 4XXX Elective	OA 4702 (4-0) Cost Estimation		NW 3285 (4-0) National Security	

CAPT Starr King, USN
28 December 2004

OR Department Program Officer
831-656-2641 ssking@nps.edu

EDUCATIONAL SKILL REQUIREMENTS
OPERATIONS ANALYSIS
CURRICULUM (360)
Subspecialty Code 3211P

As revised during September 2004 OA Curriculum Review, approved by Curriculum Sponsor OPNAV (N81) on 12 October 2004, and recorded by the Director of Naval Education and Training (N00T) on 3 November 2004.

1. BASICS: The graduate will possess the mathematical skills required to support graduate study in operations research and have the ability to use stand alone and network computers as a tool to aid in analysis.

2. MODELING UNCERTAINTY: The graduate will be well-versed in applications of probability and statistics to the modeling, simulation, and analysis of military decision problems.

3. OPTIMIZATION: The graduate will be able to formulate and solve a wide variety of optimization problems and also be conversant with the major uses of such models in DoD and the private sector.

4. STOCHASTIC MODELING: The graduate will be able to formulate and solve problems involving stochastic processes (processes with uncertainty over time) and also be familiar with the major applications of such models.

5. SIMULATION: The graduate will be able to construct and utilize Monte Carlo simulations of combat and other processes that evolve in time, and will be able to deal with statistical issues associated with the need for replication.

6. WARFARE ANALYSIS: The graduate will be familiar with U.S./Allied and potential enemy capabilities, doctrine, tactical and logistical support concepts. The graduate will be able to model and analyze military operations using Operations Analysis techniques, and be able to develop new tactical concepts based on theory and exercise reconstruction and analysis.

7. HUMAN FACTORS: The graduate will be familiar with the man-machine interface and also will be able to quantify the limitations imposed on systems designed for use by human operators.

8. SYSTEMS ANALYSIS: The graduate will understand the basic principles of economics and systems analysis as well as their application to various defense problems.

9. JOINT MARITIME STRATEGY: The graduate will have a knowledge of development and execution of military strategy, the effects of technical developments on warfare, an understanding of the means of formulation of U.S. policy, the roles of military forces and joint planning, and current issues in defense organization.

10. PRACTICE: The graduate will have gained experience working on all aspects of an analytical study and will demonstrate the ability to conduct independent analytical studies and proficiency in presenting the results both orally and in writing.

Curriculum Sponsor and ESR Approval Authority
Director, Assessment Division (N81)
September, 2004
Approved by N00T via letter Ser N00T/4U799282 of 3 Nov 2004

Joint Operational Logistics w/JPME

Note: May be tailored to meet unique requirements

Does not include a "Refresher" Quarter: Single Variable Calculus, Finite Math, and Vector Algebra

Q1	MA 3042 (4-0) Linear Algebra	MA 1115 (4-0) Multivariable Calculus	OA 3101 (4-1) Probability	OA 2200 (3-1) Computation I	OA 2900(1-0) Workshop
Q2	OA 3610 (4-0) Intro Naval Logistics	OA 3304 (4-0) Decision Theory	OA 3102 (4-2) Statistics	OA 3200 (4-1) Computation II	OA 2900(1-0) Workshop
Q3	OA 4611 (4-0) (X2) Jnt & Combined Logistics	OA 3201 (4-0) Linear Programming	OA 3103 (4-1) Data Analysis	OA 3301 (4-0) Stoch Models I	OA 2900(1-0) Workshop
Q4	OA 3501 (4-0) Inventory Theory	OA 4201 (4-0) Nonlinear Programming	OA 4655 (4-0) Joint Combat Modeling	OA 3302 (4-0) System Simulation	OA 2900(1-0) Workshop
Q5a	OA4501 (3-0) (X2) Supply Seminar (SC Only)	OA 4202 (4-0) (X2) Network Flows	OA 4801 (4-0) Spreadsheet Modeling (X2) (USMC/Intl)		
Q5b	OA 3900 (5-0) Experience Tour				
Q6	OA 0810 (0-8) Thesis Research	OA 4612 (4-0) Logistics Models	OA 4XXX Elective (4-0)		NW 3275 (4-0) Joint Maritime Operations
Q7	OA 0810 (0-8) Thesis Research	OA 4XXX Elective (4-0) (USMC/Intl)	OA 4801 (4-0) Spreadsheet Modeling (X2) (SC Only)	OA 4604 (4-0) Wargaming Analysis	NW 3276 (2-2) Joint Maritime Operations
Q8	OA 0810 (0-8) Thesis Research	OA 4XXX Elective (4-0)	OA 4602 (4-0) Joint Campaign Analysis		NW 3285 (4-0) Security Decsion Making

CAPT Starr King, USN
14 December 2005

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EDUCATIONAL SKILL REQUIREMENTS
JOINT OPERATIONAL LOGISTICS
CURRICULUM (361)
Subspecialty Code 3212P

1. BASICS: The graduate will possess the mathematical and computing skills to support quantitative analysis.

2. MODELING UNCERTAINTY: The graduate will be well versed in probability and statistics and their application to Operations Research (OR) problems.

3. OPTIMIZATION: The graduate will be able to formulate and solve a wide variety of optimization problems and also be conversant with the major uses of such models in DoD and the private sector.

4. STOCHASTIC MODELING: The graduate will be able to formulate and solve problems involving stochastic processes (processes with uncertainty over time) and be familiar with the major applications of such models.

5. JOINT LOGISTICS: The graduate will understand naval and joint logistics systems, joint planning systems, military and commercial transportation systems of all types, supply systems, maintenance, engineering, and health services and the use of analysis in all aspects of planning for the logistics support of joint forces.

6. ANALYSIS of MILITARY OPERATIONS: The graduate will be familiar with U.S., Allied and potential enemy capabilities, and will be able to model and analyze joint military operations using OR techniques. The graduate will also be able to develop and evaluate new tactical and logistics concepts for the range of operations from humanitarian assistance/disaster relief to combat.

7. SYSTEMS ANALYSIS: The graduate will understand the basic principles of economics and system analysis as well as their application to various defense problems.

8. PRACTICE: The graduate will have gained experience working on all aspects of an analytical study in the field of joint operational logistics. Specifically, the graduate will demonstrate the ability to conduct independent analytical studies and proficiency in presenting the results both orally and in writing.

9. JOINT PROFESSIONAL MILITARY EDUCATION (JPME): Graduates will be prepared to transition from specialized technical duties to assignments that require a broad understanding of national policy and strategy, resource allocation and management, and joint and combined operations. This ESR is fulfilled by completing the Naval War College course sequence leading to Service Intermediate-level Professional Military Education (PME) and Joint PME Phase I credit. Navy students take the NWC course sequence; the sequence is open to other students as desired.

Curriculum Sponsor and ESR Approval Authority

As proposed to
Director, Material Readiness and Logistics (N4)
OPNAV Staff
Following 5 October 2005 OL Curriculum Review
(Pending N17 approval)

Human Systems Integration w/ JPME

Note: May be tailored to meet unique requirements

Quarter 1 (Winter 2004)	SI4001 (4-1) Systems Engineering & Architecture	OA3402 (3-0) Research Methods for Performance Assessment	MA1010 (5-0) Algebra & Trigonometry	GB3010 (3-0) Organizational Behavior	Friday Noon Seminar	
Quarter 2 (Spring 2004)	OA3401 (3-1) Human Factors in System Design	OS3111 (3-1) Probability & Statistics for HSI & MOVES	MN3331(5-1) Systems Acquisition & Program Management	MN3111 (4-0) Human Resource Management	**Friday hourly Seminar in HSI**	
Quarter 3 (Summer 2004)	OA4401 (4-0) Individual Performance: Sensation, Perception & Cognition	OS3112 (4-2) Statistics & Design of Experiments	OA4603 (4-0) Test & Evaluation	GB3070 (4-0) Economics of the Global Defense Environment	**Friday hourly Seminar in HSI**	**JPME (Optional)**
Quarter 4 (Fall 2004)	OA4406 (3-1) Survivability, Habitability, Environmental Safety and Occupational Health	OS3113 (4-1) Data Analysis for HSI & MOVES	MN4125 (4-0) Managing Planned Change in Complex Organizations	MN4115 (4-0) Training Foundations & Management	**Friday hourly Seminar in HSI**	**JPME (Optional)**
Quarter 5 (Winter 2005)	OA4404 (3-1) Team Performance & Decision Making	MV4001 (4-0) Human Factors in Virtual Environments	OA4701 (4-0) Techniques in Manpower Modeling	GB3012 (3-0) Communications for Managers	**Friday hourly Seminar in HSI**	**JPME (Optional)**
Quarter 6 (Spring 2005)	OA4402 (4-0) Skilled Operator Performance & Training Systems	OA4407 (3-1) Physically Based Modeling, Anthropometry & Biomechanics	6 week Experience Tour	6 week Experience Tour	**Friday hourly Seminar in HSI**	**JPME (Optional)**
Quarter 7 (Summer 2005)	OA0810 Thesis Research	OA0810 Thesis Research	Elective	Elective	**Friday hourly Seminar in HSI**	**JPME (Optional)**
Quarter 8 (Fall 2005)	OA0810 Thesis Research	OA0810 Thesis Research	Elective	Elective	**Friday hourly Seminar in HSI**	**JPME (Optional)**

CAPT Starr King, USN
28 December 2004

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PROVISIONAL EDUCATIONAL SKILL REQUIREMENTS (P)ESRs

HUMAN SYSTEMS INTEGRATION CURRICULUM

for the

Naval Postgraduate School

Monterey, California

The goal of this curriculum is to educate military officers and civilian officials of the United States in Human Systems Integration. The delivery method is an in-resident course at the Naval Postgraduate School

1. BASICS: The graduate will recognize the human as the most valuable component in technology and weapon systems. The graduate will possess the skills necessary to function as a specialist in HSI. Graduates will possess a thorough background in all HSI components: Human Factors Engineering; Manpower, Personnel & Training; System Safety; Human Survivability; Habitability; and Health Hazards.

2. DATA ANALYSIS: Graduates will understand and be able to apply the statistical methods and tools necessary to perform analyses of data from human systems integration studies. They will have the requisite knowledge that enables successful application of these analytical methods and tools within the context and constraints of military operations or system development.

3. RESEARCH DESIGN: Graduates will be able to investigate a problem in HSI, formulate a research question, review pertinent literature, develop appropriate data collection protocols, analyze the data appropriately and interpret the results. Graduates will be able to apply these research principles in both field and laboratory settings. Graduates will demonstrate the ability to present research findings in written and oral format to both technical and non-technical audiences.

4. HUMAN PERFORMANCE: Graduates will understand the basis of human performance including human information processing, perception, cognition, decision-making, and motor control. Graduates will understand current theory and practice in assessing cognitive factors that affect human performance such as attention, memory, situation awareness, stress, fatigue, and motivation. Graduates will understand current scientific knowledge of factors affecting human performance and human error.

5. MODELING: Graduates will be able to apply HSI principles to human modeling capabilities and human-in-the-loop simulations. They will demonstrate the capability to apply human modeling techniques to analyses of military systems development and effectiveness.

6. ORGANIZATIONAL BEHAVIOR: Graduates will understand the political, organizational, social, and economic issues associated with integrating human-machine systems into organizational cultures and environments.

7. SYSTEM ACQUISITION: Graduates will understand and be able to apply the basic principles of defense acquisition.

8. MANPOWER, PERSONNEL AND TRAINING: Graduates will understand the importance of properly assessing, screening, selecting, training, and integrating the human into military systems. This process includes understanding the empirical basis for recruitment, selection and classification, training, and retention of personnel. Graduates will understand current and emerging technologies that contribute to personnel success and performance such as automation, training systems technologies, and job aids.

9. ENVIRONMENT AND SAFETY: Graduates will acquire a thorough understanding of the environmental factors that influence human performance, effectiveness, and safety in the high stress and hazardous environments commonly encountered in military operations. Graduates will acquire the knowledge and skills necessary to analyze environmental and safety issues for their impact on systems effectiveness and personnel safety.

10. JOINT PROFESSIONAL MILITARY EDUCATION: Students will be encouraged to complete the Joint Professional Military Education (JPME) program. This sequence develops an understanding of warfighting within the context of operational art. Topics include: national military capabilities and command structure, joint and service doctrine, joint planning and execution, and joint multinational forces and integration at the operational level of war. JPME includes coursework in wargaming designed to develop an appreciation of the art of war.

Approved as Provisional ESRs

N00TB & N12 letter "PESR APPROVAL LETTER REV B 15 DEC 04.doc" received by OR Department Program Officer via email on 15 January 2005

APPENDIX B

How to Write About Operations Research

Gerald G. Brown
Distinguished Professor of Operations Research
Naval Postgraduate School
Monterey, California 93943
19 July 2004

As an operations researcher (OR), sooner or later you will be expected to write a technical publication. The following exposes and clarifies what will be expected of you as an OR, and what you should expect from yourself. All of this applies to anything you write, from an executive summary to a full technical publication you author, or edit. Hereafter, I call this product your "publication." You may love the mathematics, but if you cannot explain your results to a non-analyst in plain English, you have failed. As an OR, you will be expected to be better at this kind of publication than anybody else --- and, you will be.

Follow this grand, unified design for any OR publication. There are five simple, essential questions you must answer in your publication, preferably in this order:

1) What is the problem?
2) Why is this problem important?
3) How will this problem be solved without your help?
4) What are you doing to solve this problem?
5) How will we know when you have succeeded?

If you do not address each of these essential elements in your outline, stop. Revise your outline. If this revision is awkward, you need to reflect on why you think you are ready to publish your work.

As OR's, we naturally focus on what we want to do (step 4). Our analytic enthusiasm sometimes overwhelms our common sense: is this problem important, or not? (step 2). Worse, we sometimes exhibit target fixation so extreme that we neglect to explain the problem we're solving (step 1). We sometimes slight step 3, even when crude, legacy methods are pretty effective. Finally, we must set standards by which our results can be objectively assessed (step 5).

Title your publication. Your title needs to convey the heart of your contribution to as wide an audience as possible. If an executive lacking OR training reads your title, would that executive understand the problem you have addressed? If your parents read the title, would they understand? Save the final wording of your title until the very last step before you submit your publication. When you do craft the final version of your title, focus on the problem and your insights, and omit terms such as "algorithm."

Abstract your publication. Your abstract will be word-limited (say, 150 words, though this varies by publication), and should convey your problem, its importance, how your problem will be solved without you, your contribution, and how we know you have made a contribution. You can use technical language here, but only if it is essential to set the context

for your publication in our technical literature. Avoid gratuitous technical jargon. Stick to plain English whenever you can. Write a tentative abstract at the outset of your publication, follow this guidance while completing your publication, but save the final edit of the abstract until second-to-last, before writing your final title.

Write an Executive Summary. You must always include an executive summary of your publication. This applies to everything you author during your career. An executive summary is a completely ***self-contained,*** plain-English survey of your contribution, suitable for consumption of any executive, or your parents. ***Your title, abstract and executive summary will be transmitted to third parties with no additional supporting material.*** An executive summary typically consists of 3-to-9 pages. Illustrations, figures, and tables may be included with legends, but these must add so much to the content that they can be included in your page-count limit. An executive summary cannot include any citations to a reference unless you include the complete attribution in the text of the executive summary. Use language your executive reader can understand, rather than technical jargon.

Use illustrations to tell your story. Use figures and pictures to draw your reader's attention, and to tell your story. The good news it that this is easy: the web offers an enormous volume of material. The bad news is that every illustration (Photo, table, graph, or whatever.) must be titled and accompanied by a very carefully-crafted legend telling the reader what you mean to convey by the display. For instance, a legend reading "Figure 17" is unacceptable, while "Figure 17: F-18 sortie availability during Operation Iraqi Freedom" may be enough. The idea is that a reader can peruse your figure and table titles, and decide what page to look up to retrieve some datum.

You should also use a legend to tell the reader what to see in each display, and how to interpret any symbol or number depicted. For instance, use the legend of a picture to tell part of your story: "The F-18 shown here can carry a wide variety of ordnance…" For instance, in a table, choose some distinctive row, or column, and quote the numeric and/or graphical entries in the legend: "For instance, the asterisk in row 3 indicates that the 88% sortie availability is below fleet standards."

Ideally, the reader can flip through your publication and just look at each of your illustrations, and its legend, and understand your story and what will be revealed by reading the complete text of your publication.

Buy a copy of ***Scientific American***, or ***American Scientist***. These are very well-edited scientific journals for the general public. Choose an article on a topic you know nothing about. Read the article as you would any document, however you choose to read it. Afterward, reflect on how you approached this foreign topic. Note the figures and their legends. See the method here?

Before you start writing, find a copy of some similar prior publication that is widely admired, and dissect it. For instance, your client, boss, thesis advisor, or mentor (hereafter, your advisor) will be happy to show you an example of the best publication in your field. Pay attention. Ask why this publication is so well-regarded. Read it. Dissect it. What are the

elements that look good to you? What are the bad points --- details that you had trouble understanding? After reading and contemplating, have another meeting with your advisor, and ask for focus on the best elements of this specimen. Reconcile your advisor's opinion with your own (it's better to deal with any differences you have with your advisor ahead of time with somebody else's publication, rather than later with your own). This is not hard to do, and won't take long. This is an excellent way to prepare yourself to author your publication, and to prepare your advisor to help.

Start each paragraph with a topic sentence. Do not surprise the reader by switching topics in the middle of the paragraph.

Make sure that just reading your paragraph-by-paragraph topic sentences conveys all of your publication. Try reading just the topic sentence of each paragraph, and skipping the rest of each paragraph. This is what any busy reader will do. Does this abstraction of your story make sense? If not, you have a structure problem: a busy reader will not likely bother to return and read the rest of all these paragraphs that never made sense on the first pass.

Avoid gratuitous backward and/or forward references. Writing is just like computer programming: you need to define your terms **before** you use them. It's true that any presentation, via any media, should "tell them what you're going to tell them, then tell them, and finally tell them what you told them," but this only means that you need an introduction, body, and conclusion. Do not end each section and/or chapter with a summary of what has appeared, and/or a prediction of what is to follow. These back- and forward-references usually signal structure problems. If you tell your story in reasonable order, you will not need these backward and/or forward pointers.

Never use footnotes. Footnotes interrupt the reader, and make the reader keep his place in your text while looking for some aside at the bottom of the page. Footnotes are a sure sign that you need to refine your outline, because you haven't been able to write a complete paragraph without jumping off your paragraph's topic.

Use (parenthetic) phrases carefully. A parenthetic statement should be an in-line corroboration, not some exception. Be careful to avoid using parentheses to insulate your ideas from any criticism. For example, "I'm right (unless I'm wrong)" equivocates, but "I'm right (and these references that are not quite on my main theme prove it)" may be acceptable. Do not (nest (parenthetic phrases)).

English has exactly one slashed term. The English language includes exactly one slashed term: **"and/or." Do not uses slashes with English** unless you are explicitly quoting verbatim some source that exhibits such ungrammatical use, or defines some term that is in common, albeit ungrammatical use. Slashed terms abound in military lexicon, but not in English exposition. Focus on English exposition.

Avoid excessive, repeated use of the same term in the same sentence or paragraph. E.g., "Missiles are difficult to maintain, but missiles are expensive, so we must carefully balance missile maintenance cost with missile availability, lest missile …" (Laughing, are you? This

is a direct quote of a report I was asked to edit. Guess how I marked it up.) When the repeated term is uncommon, its repeated use is even more alarming. Rewriting: "Missiles are difficult to maintain, but they are expensive, so we must carefully balance their maintenance cost with their availability, lest they…"

Use active voice. Passive voice puts the reader to sleep. It's easy to change the passive "Missile failures result from poor maintenance," to active "Poor maintenance causes missile failures."

Use present tense. Even if your reference is old, if you are drawing some current inference from this reference, **use present tense**. E.g., "Dantzig [1951] introduces a remarkable specialization of his simplex method for transportation network problems." Use past tense only if this is absolutely necessary to keep the sequence of contributions straight. E.g., "Glover, et al. [1974] ***reported*** the first fast simplex specialization for minimum-cost, capacitated pure network flow models, but Bradley, et al. [1977] ***develop*** a faster simplex specialization." Better, say, E.g., "Glover, et al. [1974] ***report*** …, but ***later*** …" Present tense carries weight with your reader. If you cannot conjure some phrasing in present tense for a reference, this is a sure sign that this reference is gratuitous.

Avoid puffery. Write direct sentences with minimal wording. Telltale words that add nothing to any well-crafted sentence are "***method***," "***methodology***," "***process***," and frequently "***algorithm***." Read any document you wish, and underline any phrase featuring any such "puff-term;" rewrite this phrase without this "puff-term." The result will be shorter, and easier to read. Here is another, too-frequent example and its repair: "~~***It interesting to note that***~~ the sky is blue."

Define just one. When describing something, define just one. For example, rather than writing "cars have doors," write "each car has doors." The latter conveys more than the former: each car has more than one door.

Have somebody else read your text to you. Make two copies of your text, keep one in hand with a pencil, and have somebody with no OR background read your other copy to you out loud. Listen well. Any hesitation, stumbling over words, restatement, or other sign of misunderstanding is a sure sign of trouble. Mark up your copy of the text as it is read to you. Rewrite. Repeat.

Your publication can be as short as it can be. You can win a Nobel Prize in less than two pages (see paper attached at the end of this document, with its key sentence highlighted). Never pad your publication for fear that someone will think you lack content. Try reading each paragraph out loud with one breath. If you get dizzy, your paragraphs are too long.

Adopt this style for references and citations. Examples of the best reference and citation styles appear in Military Operations Research instructions for authors, http://www.mors.org/publications/mor/edpolicy.htm

For an article, use the form:

Watson, J. and F. Crick 1953. A Structure for Deoxyribose Nucleic Acid, Nature, Vol. 171 737-738.

For a book, cite:

Morse, P. and G. Kimball. 1951. *Methods of Operations Research.* MIT Press, Cambridge, MA,

For an article in a collection, or a chapter in a book, show:

P. Morse and G. Kimball, 1951, *Methods of Operations Research.* MIT Press, Cambridge, MA, Chapter 4, "Strategical Kinematics," 61-80.

For a web reference, list:

Federation of American Scientists [2004] "C-201/HY-2/SY-1 CSS-N-2/CSS-C-3/ SEERSUCKER," http://www.fas.org/man/dod-101/sys/missile/row/c-201.htm, accessed 14 July.

Note that each citation, for instance Akgul [1998b], exhibits the author(s) and year of publication. This permits your reader to decide whether or not to stop reading your text and look in your references, or just read on. Note that the references feature the author name(s) and year, then the title, then the specifics for a journal article, textbook, chapter in a textbook, or whatever. This makes it fast and easy to match a text citation with the reference entry, minimizing distraction from your text. Akgul [1998b] evidently has two references in that year, and the "b" serializes the second with no ambiguity. The preceding sentence uses Akgul as its subject, thus his name appears outside the brackets.

If you need to cite an email, phone call, or conversation, list in your references the name(s) of those corresponding with you, the year, then "private communication" and the date of this; citing a private communication is sometimes unavoidable, but never preferred to an archival, written reference.

Talk is cheap. Some in our business say ***"if it isn't written down, it never happened."*** If you cannot get a written reference, write out your best understanding of the conversation you report, and retain this copy in case someone asks you questions years from now.

Never adopt the citation style, e.g., "[31] reports a remarkable specialization of the simplex method^2." Gad.

Web citations are (still) notoriously ephemeral: if you cite a web reference, list the author(s), sponsoring agency, year, title (or your best effort to conjure a title), the complete web address, *and the calendar date of your latest access*. Retain an electronic or paper copy of the key material in the reference.

For archival purposes, retain personal copies of your key references, and of all web references, and state in your conclusions "all references are available from the author." Better yet, leave a package with your advisor and state "all references are available from the author and/or his advisor."

Avoid excessive use of "and/or." Have you noticed a lot of "and/or's" herein? Annoying, isn't it? "And/or" means "both, or either." This is too often an equivocation. Herein, I have intentionally used and/or too frequently, but always with its exact denotation. You can almost always substitute "or." I should do so.

Choose a style manual, and use it. I'm fond of **The Elements of Style** (any edition) by Strunk, White and Angell. For just $8, this is short, well-written, and easy to use. This is where to find advice on "which" versus "that," "since" versus "because," etc.

Use a professional editor. An editor can quickly revise your exposition and dramatically improve it. Editors are not expensive. There's no shame in depending on an expert to tune up your writing --- you do use a mechanic to tune up your car, don't you?

Take an English composition course. Even though you already hold a college degree and likely a graduate degree too, if you can't write a complete paragraph to save your life, you can still learn how. Every local community college offers a beginning English composition course. You will be assigned short essays that are personally edited and graded by your instructor. In a matter of weeks, you can remedy your dark secret. Believe me, this works.

Work at it. For most of us, writing is hard work. But, there is no substitute for good English exposition.

Your publication will define your career. Even if this is the only publication you ever author, you will prove that you have earned your place in the company of scholars. If you ever find yourself competing for some position, your publication will be a distinguishing difference between you, and any competitors.

Wayne Hughes and Kirk Yost reviewed this and permit me to say so. I also acknowledge and admire my wordsmith colleagues who make writing appear so natural and easy. I have long wondered why writing is so hard for the rest of us. As an OR, I have analyzed this important problem (sic) for decades, authored, advised and revised hundreds (maybe more than a thousand) theses and technical reports, and respond with the advice herein. I have followed my own advice and coerced my students and colleagues to follow my lead. I also credit INTERFACES' Mary Haight for her humbling editorial revisions that provide signal lessons in crystal-clear English exposition. Thanks to all of you.

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A structure for Deoxyribose Nucleic Acid

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2 April 1953

MOLECULAR STRUCTURE OF NUCLEIC ACIDS

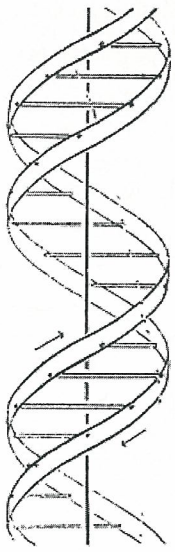
A Structure for Deoxyribose Nucleic Acid

We wish to suggest a structure for the salt of deoxyribose nucleic acid (D.N.A.). This structure has novel features which are of considerable biological interest.

A structure for nucleic acid has already been proposed by Pauling and Corey (1). They kindly made their manuscript available to us in advance of publication. Their model consists of three intertwined chains, with the phosphates near the fibre axis, and the bases on the outside. In our opinion, this structure is unsatisfactory for two reasons: (1) We believe that the material which gives the X-ray diagrams is the salt, not the free acid. Without the acidic hydrogen atoms it is not clear what forces would hold the structure together, especially as the negatively charged phosphates near the axis will repel each other. (2) Some of the van der Waals distances appear to be too small.

Another three-chain structure has also been suggested by Fraser (in the press). In his model the phosphates are on the outside and the bases on the inside, linked together by hydrogen bonds. This structure as described is rather ill-defined, and for this reason we shall not comment on it.

We wish to put forward a radically different structure for the salt of deoxyribose nucleic acid. This structure has two helical chains each coiled round the same axis (see diagram). We have made the usual chemical assumptions, namely, that each chain consists of phosphate diester groups joining ß-D-deoxyribofuranose residues with 3',5' linkages. The two chains (but not their bases) are related by a dyad perpendicular to the fibre axis. Both chains follow right- handed helices, but owing to the dyad the sequences of the atoms in the two chains run in opposite directions. Each chain loosely resembles Furberg's2 model No. 1; that is, the bases are on the inside of the helix and the phosphates on the outside. The configuration of the sugar and the atoms near it is close to Furberg's 'standard configuration', the sugar being roughly perpendicular to the attached base. There is a residue on each every 3.4 A. in the z-direction. We have assumed an angle of 36° between adjacent residues in the same chain, so that the structure repeats after 10 residues on each chain, that is, after 34 A. The distance of a phosphorus atom from the fibre axis is 10 A. As the phosphates are on the outside, cations have easy access to them.



This figure is purely diagrammatic. The two ribbons symbolize the two phosphate—sugar chains, and the horizontal rods the pairs of bases holding the chains together. The vertical line marks the fibre axis

The structure is an open one, and its water content is rather high. At lower water contents we would expect the bases to tilt so that the structure could become more compact.

The novel feature of the structure is the manner in which the two chains are held together by the purine and pyrimidine bases. The planes of the bases are perpendicular to the fibre axis. The are joined together in pairs, a single base from the other chain, so that the two lie side by side with identical z-co-ordinates. One of the pair must be a purine and the other a pyrimidine for bonding to occur. The hydrogen bonds are made as follows : purine position 1 to pyrimidine position 1 ; purine position 6 to pyrimidine position 6.

If it is assumed that the bases only occur in the structure in the most plausible tautomeric forms (that is, with the keto rather than the enol configurations) it is found that only specific pairs of bases can bond together. These pairs are : adenine (purine) with thymine (pyrimidine), and guanine (purine) with cytosine (pyrimidine).

In other words, if an adenine forms one member of a pair, on either chain, then on these assumptions the other member must be thymine ; similarly for guanine and cytosine. The sequence of bases on a single chain does not appear to be restricted in any way. However, if only specific pairs of bases can be formed, it follows that if the sequence of bases on one chain is given, then the sequence on the other chain is automatically determined.

It has been found experimentally (3,4) that the ratio of the amounts of adenine to thymine, and the ration of guanine to cytosine, are always bery close to unity for deoxyribose nucleic acid.

It is probably impossible to build this structure with a ribose sugar in place of the deoxyribose, as the extra oxygen atom would make too close a van der Waals contact. The previously published X-ray data (5,6) on deoxyribose nucleic acid are insufficient for a rigorous test of our structure. So far as we can tell, it is roughly compatible with the experimental data, but it must be regarded as unproved until it has been checked against more exact results. Some of these are given in the following communications. We were not aware of the details of the results presented there when we devised our structure, which rests mainly though not entirely on published experimental data and stereochemical arguments.

It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material.

Full details of the structure, including the conditions assumed in building it, together with a set of co-ordinates for the atoms, will be published elsewhere.

We are much indebted to Dr. Jerry Donohue for constant advice and criticism, especially on interatomic distances. We have also been stimulated by a knowledge of the general nature of the unpublished experimental results and ideas of Dr. M. H. F. Wilkins, Dr. R. E. Franklin and their co-workers at King's College, London. One of us (J. D. W.) has been aided by a fellowship from the National Foundation for Infantile Paralysis.

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APPENDIX C

The Teachers' Forum: The Operations Analysis Curriculum at the Naval Postgraduate School

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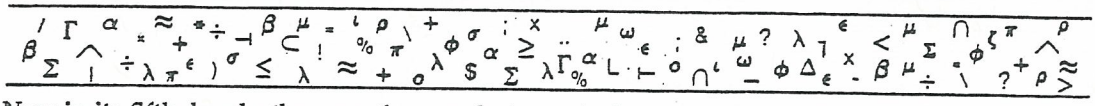

Now in its fifth decade, the operations analysis curriculum at the Naval Postgraduate School is one of the oldest and most respected masters programs in OR/MS in the United States. In this article, Alan Washburn describes the origins and evolution of the program and compares it to the ORSA/TIMS "model" curriculum [Dyer et al. 1993].

The operations analysis program at NPS is unlike most other masters programs in its exclusive connection with the military. However, what is most interesting about this program to an outsider is its "intimate relationship with a customer who pays close attention to the fate of graduates." The scrutiny and feedback this program receives from the employers of its graduates must be a major factor behind its long-term success. Those of us who teach in nonmilitary programs typically have more distant relationships with our "customers": employers and other faculty who rely on us to teach quantitative skills. While we can envy the close customer contact at NPS, perhaps we can also emulate it through closer contacts with our various customers.

—Stephen G. Powell

The operations analysis curriculum at the Naval Postgraduate School has responded to a variety of pressures for change in the 45 years since its founding, and its managers have continually wrestled with the theory-versus-practice question that has recently preoccupied ORSA/TIMS and INFORMS. Even though NPS is almost unique among graduate schools on account of its navy sponsorship, our experiences may still be of interest to others.

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PROFESSIONAL—OR/MS EDUCATION
MILITARY

INTERFACES 26: 5 September–October 1996 (pp. 71–80)

The Naval Postgraduate School (NPS) can trace its history back to 1897, when the Naval Academy initiated a course in naval construction in response to the British Board of the Admiralty's decision to exclude foreigners from its Naval College [Rilling 1972]. NPS still maintains a successor curriculum called naval/mechanical engineering, but by now it has been joined by 38 other curricula in a wide variety of scientific fields, one of which is the operations analysis (OA) curriculum. Most students are US Navy officers, but significant numbers are from other services and other countries (Figure 1). The international group includes students from over 30 countries (including Great Britain!).

Curricula range in length from 18 to 36 months, with OA having the median length of 24 months. Completion of his (or her—nine percent of NPS students are female) assigned curriculum qualifies a navy officer in a *subspecialty*. Formally, this subspecialty qualification—not the award of a master's degree that usually occurs simultaneously—is the justification for graduate education. However, all navy officers attending NPS do so voluntarily, since each must commit to remaining in the navy for a certain period of time after graduation, and the award of a degree plays a strong motivational role because of its importance in the civilian world that every officer must contemplate reentering some day.

The typical navy officer-student spends about five years on active duty after obtaining a bachelor's degree and before entering NPS. The bad news about these five years is that the first six months of most curricula must be devoted to essentially undergraduate material so that students can refresh or update what has atrophied or become out of date in the meantime. The good news is that the five years bring a maturity of judgment and an awareness of potential application areas that are of great value when it comes time to write a thesis, as nearly all curricula require. Students are paid at the customary rate for their rank throughout their tenure at NPS, so most of the cost to

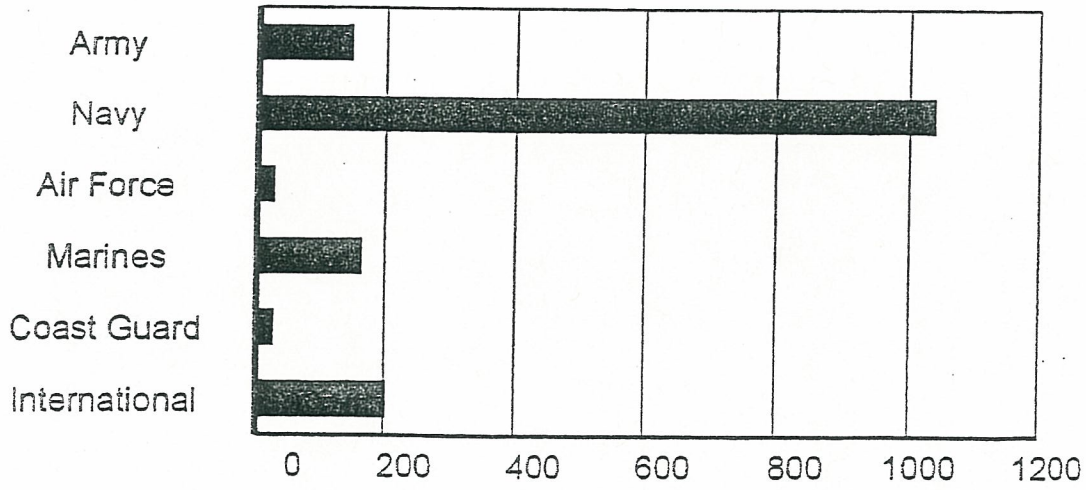

Figure 1: The 1,600 students currently enrolled at NPS are partitioned into six groups.

the services of graduate education for their officers is actually in student salaries. Students are in school during all four of NPS' yearly quarters, lest this cost be even larger. A *quarter* is 12 weeks long, leaving four weeks per year for breaks.

Most of the 400 faculty members at NPS are civilians, and it is the faculty who manage NPS curricula in the short term. The Navy interacts only a little with the faculty on a daily basis, but still maintains quality control of curricula through a series of biannual reviews conducted by each curriculum's *sponsor*, a Navy officer charged with ensuring the well-being of the associated subspecialty. If the sponsor determines that graduates lack some capability or that some other capability turns out not to be useful, then he will describe the problem and expect a correction. This intimate relationship with a customer who pays close attention to the fate of graduates is one of the things that distinguishes NPS from other graduate schools; the customer has a formal feedback mechanism and, if necessary, ultimate power over the curriculum. The relationship between the faculty and the sponsor is perhaps similar to the relationship between the management and board of directors in a corporation, except that the sponsor replaces profitability with "suitability of graduates for the subspecialty jobs we have identified for them."

A letter from a high-ranking officer that one's work has made a difference can be very influential.

Partly because NPS wishes to remain an attractive destination for new faculty, it structures academic life to be similar to that at other graduate schools. Faculty are organized into 11 departments, such as mechanical engineering and OR. Faculty members are expected to do research, and they must seek research sponsors and publish the results. In fact, Woolsey and Maurer [1995] link us (the OR department, that is) with Stanford, Berkeley, University of Southern California, UCLA, and MIT as schools interested in "pushing back the frontiers of theory in OR." They are correct. The tendency of OR graduate curricula to be overly theoretical is sometimes blamed [Geoffrion 1992] on requirements for faculty to publish. We claim that our curricula are more on the practical side, but this practical bent does not stem from lack of a desire to push back frontiers.

Another reason sometimes given [White 1991] for overly theoretical OR curricula is that terminal master's students must usually share classes with students for whom the master's degree is just a stepping stone to a PhD. NPS does offer a PhD in OR, but the number of PhD students is so small (one or two in residence) that that kind of influence is unlikely.

The promotion-and-tenure process at NPS is conventional in the sense that proposals originate in the individual's department and propagate upwards through multiple administrative levels. NPS criteria (in all fields) have shifted over the last decade to provide more weight to applied work—a letter from a high-ranking military officer to the effect that one's work has actually made a difference can be very influential. NPS has a well-organized system for collecting student feedback about teaching.

Summaries of this feedback play an important role in promotion and tenure decisions, as is natural given the maturity of the students.

History and Current Status of the OA Curriculum

In 1951, at its founding, the OA curriculum was supported mainly by the physics and mathematics departments—there was no OR department then. The original two-year curriculum included six months devoted to practical work that was expected to lead to a thesis. It also included 11 semester-length courses in physics. The physics courses have since been gradually displaced by an experience tour and by additional courses in probability and statistics, computer programming, optimization, human factors, and economics, a process that accelerated when the OR department was created in 1961. The last physics course disappeared in 1993. This displacement of physics was also occurring elsewhere within the OR profession at about the same time [Larson 1992]. It is the biggest qualitative change in the curriculum since its founding, but there have also been others.

The student population increased about five-fold in the 1960s ("the McNamara years"), and the sponsor began to emphasize systems analysis in defining the subspecialty. The curriculum was renamed the operations research systems analysis (OR/SA) curriculum in 1965, and the course mix changed correspondingly. A decade later, part of the navy became concerned that tactical development was languishing. It was suggested that a new curriculum was needed, and there was a debate about what to do. In the end, it was decided to increase the OR/SA tactical content and change the name of the curriculum back to the more neutral operations analysis (OA). A similar concern with logistical planning led in 1986 to the creation of a new operational logistics (OL) curriculum, with a separate sponsor, rather than a modification of the OA curriculum. OL graduates take many of the same courses as OA graduates and get the same OR master's degree, but they qualify for a different subspecialty and therefore for different jobs. Currently about 15 officers per year graduate from OL, compared to about 60 per year from OA.

The OA curriculum permits a small amount of flexibility in the form of "options," all of which lead to the same subspecialty and the same degree. For example, the land combat option was developed when army students were accepted in 1965. The joint and naval warfare option (Table 1) is taken by most army and navy officers, and is therefore the most popular. The presence of the cost estimation course testifies to the influence of the sponsor: the course is not new, but it has not always been required. Attendance at a series of application-oriented seminars on topical subjects is also required.

The OA curriculum is serviced by several departments, but most of the teaching (all of the OA courses in Table 1) is done by faculty in the OR department. The OR department includes 40 faculty members, most of whom hold PhD degrees, plus three chairs in applied systems analysis, tactical analysis, and joint warfare. Nine of the 40 faculty are military—seven navy and two army. The navy instructors occupy seven of the 167 jobs in the navy's OA subspecialty. The civilian faculty can be roughly divided into stochastic types, op-

1	OA2200 (4-0) Computational Methods I	MA1118 (5-2) Multivariable Calculus	MA3402 (4-0) Linear Algebra	OA3101 (4-1) Probability
2	OA3200 (4-0) Computational Methods II	AS3610 (4-0) Micro Economics	MA3110 (4-0) Intermediate Analysis	OA3102 (4-1) Probability and Statistics
3	OA3201 (4-1) Linear Programming	OA3401 (4-0) Human Performance Measures	OA3301 (4-0) Stochastic Models I	OA3103 (4-1) Statistics
4	OA4202 (4-0) Network Flows and Graphs	OA3602 (4-0) Search Theory and Detection	OA3302 (4-0) OA Systems Simulation	OA3104 (4-1) Data Analysis
5	OA4301 (4-0) Nonlinear Programming		OA4655 (4-0) Air-Land-Sea Analysis	
	Experience Tour			
6	OA4301 (3-2) Stochastic Models II	OA4654 (4-0) Air-Land Models	OA4604 (4-0) Wargaming Analysis	Thesis Research
7	Elective	OA4602 (4-0) Joint Campaign Analysis	OA4603 (3-2) Test and Evaluation	Thesis Research
8	OA4702 (4-0) Cost Estimation	NS3252 (4-0) Joint and Maritime Strategy	Elective	Thesis Research

Table 1: Each row corresponds to one of the eight quarters of the joint and naval warfare option of the OA curriculum, with four columns because students take four courses in each quarter. The two courses in the fifth quarter are intense and short to make room for the six-week experience tour. OA courses are taught by OR faculty, others are not. The (M-N) notation means that there are M hours of lecture and N hours of lab per week.

timizers, and a third group that will admit to no label other than OR. The inevitable rivalry among these groups is usually good natured. We undertake a variety of research projects, both theoretical and applied, with the applications being mostly to problems within the Department of Defense. As a sampling of publications, the last five open literature publications in 1995 are listed below. The first names of OR faculty members are spelled out to distinguish them from non-NPS coauthors:

—Almeida, R.; Gaver, Donald; and Jacobs, Patricia., "Simple probability models for as-

sessing the value of information in defense against missile attack," *Naval Research Logistics*, Vol. 42, No. 4, pp. 535–548.
—Buss, Arnold and Lawrence, S., "Economic analysis of production bottlenecks," *Mathematical Problems in Engineering*, Vol. 1, No. 2, pp. 341–363.
—Kemple, William.; Sadler, P.; and Strauss, D., "Extending graphic correlation to many dimensions: Stratigraphic correlation as constrained optimization," *Graphic Correlation*, Keith Mann and H. Richard Lane, eds., Society for Sedimentary Geology, Tulsa, Oklahoma, pp. 65–82.
—Read, Robert., "The evolution of a selection system," *Naval Research Logistics*, Vol. 42, No. 7, pp. 1099–1114.
—Washburn, Alan., "Finite method for a nonlinear allocation problem," *Journal of Optimization Theory and Applications*, Vol. 85, No. 3, pp. 705–726.

The first paper is a military application (coauthor Almeida is a former OA student from Portugal's navy), the next two are nonmilitary applications, the fourth is a study of statistical questions arising in selecting the annual teacher of the year at NPS, and the last is a methodological paper motivated by a military application.

Operational Curricula

The OR department does nearly half of its teaching to students who do not receive the master's degree in OR. Much of this is service courses in probability and statistics—the relevant faculty were moved to the OR department shortly after it was formed. There are also service courses titled "Introduction to OR for xxxx," with xxxx including "management" and "naval intelligence." Each of these is a single quarter survey usually founded on a software package combining a variety of OR techniques, with applications tailored to the xxxx group of students. Most of these service courses would be familiar to any OR academic.

In some cases, the department's service is deeper than just a course or two. Beginning in 1972, NPS established several "operational" curricula, the first of which was the undersea warfare (UW) curriculum. UW students spend much of their time learning about sound propagation, signal processing, and oceanography, the technology of the UW world. Since the intent of the curriculum is to turn out warfighters rather than engineers, however, UW students also need to study the development and evaluation of tactics, software, and equipment. Consequently the UW curriculum includes several courses taught by the OR department (Applied Probability, Computer Simulation, Tactical Decision Aids, and others), and the overseeing committee includes OR faculty. The OR department plays a similar role in the information warfare; space systems operations; and joint command, control and communications curricula.

Roughly speaking, one could obtain one of the current operational curricula by starting with the 1951 OA curriculum and modernizing or specializing its physics courses. The coexistence of the current OA curriculum and the four operational curricula at NPS, each of which might trace its heritage to the 1951 OA curriculum, is evidence that there is no correct design for an OR master's program—a wide-ranging field such as ours has room for a variety of useful solutions.

Practice

NPS requires a thesis for the OR master's

degree, which puts us in the minority according to INFORMS [1995]. Nearly all these describe applications, so the thesis requirement should be regarded as an enduring part of the OA curriculum's emphasis on practical work. Practical or not, the thesis is also the student's most important exercise in written communications. Here is a selection of thesis titles and authors for Fall/95 OA graduates:

—"Optimal airfield capacity expansion," Lieutenant David Chapates, US Navy;

—"Shallow water tactics for the Mark 50 Torpedo directed search pattern," Lieutenant Kyle Kliewer, US Navy;

—"Route optimization model for strike aircraft," Captain Steve Lee, Singapore Airforce;

—"A waste management plan for US Navy ships," Lieutenant Nancy Paulsen, US Navy; and

—"Optimizing strategic sealift," Captain Gust Pagonis, US Army.

Most students start working on their theses in the fifth quarter during the experience tour, a six-week period during which the student leaves NPS and examines OR problems from the viewpoint of a host organization. The student typically does not select his thesis advisor until after returning from the tour, but may still contact faculty during the tour to discuss models, data sources, and so forth. Experience tours are expensive in terms of time and money, but there is a lot to be said for getting away from the academics and dealing with people who think they have a real problem, rather than just an "exercise".

While the thesis and tour are the centerpiece of practice, the OA curriculum also includes the aforementioned seminar program, plus practical material within formal courses. There are two schools of thought with regard to incorporating practical material in courses. One is that early courses should be primarily theoretical, with practical experience coming in later courses that have "applied" in their titles, or perhaps even in capstone courses designed to "put it all together." There is something to be said for this approach—clearly one can't apply something until one has learned it—but we have found it hard to carry out. In practice, capstone courses end up considering problems where some techniques are heavily used and others are omitted entirely. There is nothing wrong with this, since it mirrors real life, but still the usefulness of all material ought to be demonstrated. This leads to the other school of thought, which is that every course ought to include applications. The OA curriculum has been influenced by both schools of thought. It is probably evident in inspecting the naval warfare option (Table 1) that Joint Campaign Analysis is a capstone course, as are such unshown electives as Problems of Naval Warfare. Many of the earlier courses also include application projects.

Like all OR curricula, the OA curriculum is a compromise.

Willemain [1994] and Powell [1995] report favorable experience with teaching nontraditional courses on the modeling process itself, courses that emphasize creativity, context, and the unimportance of "correctness" in dealing with real problems. The OA curriculum does not currently re-

quire such a course, although many OA students do take an elective that is devoted to the modeling process, rather than to any particular technique. Nor does the OA curriculum include formal material in other important practical areas such as the history of OR or communication skills. There simply isn't enough time, or, put another way, the OR faculty feel that the material that is in the curriculum is more important. Like all OR curricula, the OA curriculum is a compromise that is very much influenced by the presence of a constraint on its length.

Communication Skills

At a retreat in 1984, the OR faculty identified written communications skills as the characteristic of our graduates most in need of improvement. It has even been suggested that a formal course in technical writing should be inserted into the OA curriculum, although this is not likely to happen because the 11 departments at NPS do not include an English department. The experience of writing a thesis helps, of course, but for some students, particularly but not exclusively foreign students, the experience is an exercise in applying something that hasn't yet been taught.

Verbal communications, especially short talks called briefings, are particularly important for military officers. Army officers arrive at NPS with some training in the area. While the OA curriculum provides no additional training, it does provide opportunities for practice and criticism. Students often brief the rest of the class on their course projects, for example. At times the curricular officer has required that all theses be briefed, but the students object because every student is required to attend every briefing, a large time commitment at a point in the eighth quarter when many theses aren't really finished. At the moment, only theses in competition for the Military Operations Research Society/Tisdale Award are briefed.

Briefings have improved in recent years with the advent of software for generating presentation materials. It is a tribute to the user-friendliness of modern software packages that computer-literate students can learn to use them without formal instruction.

Computers

The OA curriculum included a course in FORTRAN programming from the time of the department's founding until 1992. FORTRAN still has its devotees, but it was replaced as a general purpose language in 1993 by Pascal, at the same time that instruction switched from the mainframe to a network of PCs. In the early decades no language other than FORTRAN was employed—the set-up cost of learning to use other languages was simply too high, so all programs were written in one general purpose language. As special purpose languages became easier to learn and use, instructors sometimes found it worthwhile to teach students how to use them, even when the students already knew FORTRAN. The use of special purpose languages has accelerated within the last decade. Today's OA graduates are familiar with Pascal, MODSIM, LINDO, GAMS, S+, APL, MAPLE, MATLAB, and various word/presentation processors by the time they leave. Service courses to other curricula may employ STORM, GPSS, FAST-QM, or MINITAB. This ease of learning and using new, special purpose languages is revolutionary in

permitting us to teach important ideas in the context of realistic problems. Graphical capabilities are especially useful. The two Computational Methods courses (Table 1) teach Visual Basic and Java; all of the other languages are taught within the courses in which they are used.

Comparison with the Model Curriculum

The ORSA/TIMS Committee for Review of the OR/MS Master's Degree Curriculum proposes [Dyer et al. 1993] a model curriculum for a terminal master's degree. It suggests a curriculum that is one year long, including time devoted to a "project/thesis," but acknowledges that a second year would permit the inclusion of an internship and additional desirable material. By comparison, the OA curriculum includes a second year because of the need for early undergraduate work and the thesis and tour requirement, and because the curriculum must meet subspecialty requirements as well as degree requirements. There is a rough but good correspondence in terms of academic content and length between the OA curriculum and the one proposed by Dyer et al. Each has heavy emphasis on probability and statistics, less heavy emphasis on other traditional OR areas, and a liberal admixture of specialization courses and projects.

Dyer et al. conducted a survey in which practitioners ranked "computer use skills" above all others in importance, including probability and statistics, and Geoffrion [1992] identifies the microcomputer and communications revolutions as two of the four major forces acting on OR/MS. The importance of these forces has surely increased with advances in networking over the last few years. The widely acknowledged importance of computers to OR, the rapid improvements in hardware and software, and most particularly the advent of computer networks have caused a continual ferment about how the subject is treated within OR/MS curricula. The OA curriculum and the model curriculum have reacted differently to this pressure. The OA curriculum devotes two courses to formal instruction in computing, using Visual Basic and Java as general purpose programming languages within which such concepts as objects, structures, and complexity can be explored. OA graduates should be able to write, debug, and criticize complicated computer programs and often do so in the course of writing a thesis. The model curriculum, on the other hand, simply makes knowledge of "an algorithmic language such as C" a prerequisite, using the time saved to introduce material on networking and telecommunications. This should produce graduates with an understanding of the architecture and limitations of the computer systems they will have to deal with, a capability that cannot be claimed for OA graduates. Thus the two curricula definitely differ about what should be taught about computers and their uses. On the other hand, both curricula make liberal use of special purpose software packages.

> The object is graduates capable of recognizing, formulating, and solving real-world operational problems.

The model curriculum contains several specialization courses that permit consider-

able variety among graduates with the same degree. This is accomplished by options within the OA curriculum, but options permit less freedom than Dyer et al. apparently have in mind. NPS is quick to distinguish between graduates of different curricula. OL graduates get the same operations research degree as OA graduates, but (just as important to a military officer) different subspecialty codes. Graduates of operational curricula, such as UW, get a different degree and a different subspecialty code. Thus, while NPS permits relatively little flexibility within the OA curriculum, other closely related curricula are available.

Dyer et al. emphasize the importance of communications skills to OR, going so far as to suggest modifying admission procedures in favor of applicants with those skills. We agree that communication skills are important, but modifying the admission procedure is not an option. We feel that our students' verbal skills are good in spite of our lack of instruction. We continue to agonize about written skills.

In terms of basic philosophy, the OA curriculum and the model curriculum are in complete agreement. Put simply, the object is to produce graduates capable of recognizing, formulating, and solving real-world operational problems.

Summary

The OA curriculum at NPS is alive and well and can be expected to remain that way as long as its graduates continue to be effective analysts. It strongly resembles the model curriculum of Dyer et al. in both content and philosophy, although there are differences. At about the time when the OA curriculum was founded, Morse and Kimball [1951, p. 1] stated that

> Operations research is a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control.

We still like that definition, even though the scientific method that we teach today at NPS would hardly have been recognizable to Morse and Kimball in 1951. Stated very simply, our goal is to produce graduates who can do that.

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APPENDIX D

A View from the FA49 Foxhole:
Operational Research and Systems Analysis

Lieutenant General David F. Melcher, U.S. Army, and
Lieutenant Colonel John G. Ferrari, U.S. Army

The tools and knowledge ORSAs bring to the analysis of joint effects and campaign plan metrics are invaluable. There is a definite need for combat analysts to be a part of the UEx and UEy battle staffs, as well as the battle staffs of both the Joint Combatant and Task Force Commander. —MG Rick Olson[1]

Operations Research Systems Analysis is not *business management, it's* warfighting capability *analysis—a critical part of the Joint, Combined Arms Team!*
—General Benjamin S. Griffin[2]

CHIEF OF STAFF of the Army (CSA) General Peter J. Schoomaker has set the Army on course to "be a more relevant and ready force—a campaign-quality Army with a Joint and Expeditionary Mindset."[3] To accomplish this transformation, the Army is examining changes made over the past 20 years, including the officer functional areas the Officer Personnel Management System (OPMS) III put into place during the late 1990s. OPMS III's emphasis on specialization and multiple career paths promotes longer tours of duty and efforts to stabilize units and eliminate unnecessary personnel turbulence.

From the perspective of the Functional Area 49 (FA49) "foxhole," the Operations Research Systems Analyst (ORSA) career field is changing to align with the Army's core competencies of training and equipping soldiers, growing leaders, and providing combatant commanders a relevant and ready landpower capability as part of the joint team.

Every organization must adapt or perish. ORSAs are no exception. Since World War II, the military operations research analyst has been critical to the military's operational and institutional success. During the past decade, however, changes to the ORSA career field and a migration of the specialty from the operational Army to the institutional Army have reduced ORSAs' opportunities to directly support the operational commander. Recognizing this shortcoming, FA49 is making changes internally and seeking changes on operational Army and joint staffs.

Driving the changes are the insights gained through the multiple deployments of analysts to Bosnia and Kosovo in Operations Enduring Freedom and Iraqi Freedom (OEF/OIF) and experiments with the unit of action and unit of employment (UEx and UEy) organizational concepts.[4] Providing coverage for deployments has been a team effort across the Army analytical community and includes civilian analysts. The insights gained show that an embedded analytical cell with G3 and G5 plans is needed to provide rigorous analysis that is operationally relevant, reaching across the entire battle staff through the staff and planning groups.

ORSA's Core Competency

ORSA's core competency is much broader than simple numerical and quantitative analysis. While ORSAs are extremely competent in quantitative analysis, their true core competency is in problem solving. They look at a problem as a complex system with many quantitative and qualitative variables, break it down, analyze its primary parts, and propose solutions. The FA49 mission statement describes ORSA's core competency best—"[to] produce analysis . . . , to underpin decisions by leaders . . . , and to enable solutions to varied and complex strategic, operational, tactical, and managerial issues."[5]

ORSAs are specialists trained in problem solving as a core competency, but the combat ORSA must be much more. Combat ORSAs must always remember they are soldiers first. The operational Army is not a "union shop" where roles and functions are contractually delineated. Deployment of FA49 analysts teaches that ORSAs must remain operationally competent across the spectrum of skills resident in joint and combined battle staffs. For example, ORSAs deployed with Combined Joint Task Force 7 (CJTF-7) to Iraq and the combined joint task forces in Afghanistan helped joint force commanders—

- Analyze the number and emplacement of medical evacuation helicopter fleets to determine future force-flow requirements.
- Recommend changes in the emplacement of counterfire radars to maximize effectiveness in identifying mortar and rocket fires aimed at base camps.
- Examine the locations of improvised explosive devices (IEDs) to determine possible enemy ammunition caches.
- Assess counter-IED procedures to reduce attacks on convoy supply routes.
- Develop metrics and assess plans and operations to adjust future combat operations.
- Analyze critical nodes and desired effects in the joint effects working group to modify operational plans.
- Analyze poll results about counterinsurgency operations to gauge the success of efforts to win the hearts and minds of the local population.
- Examine militia reintegration as a way to begin disarming private armies.
- Assess the effectiveness of combat and security operations on enemy activity.

These problems, solved by just a few deployed analysts over the past year, demonstrate the need for embedded analysts who are operationally competent; understand combat operations across the range of the entire joint planning group and battle staff; and have tactical, operational, strategic, and joint knowledge that transcends statistics and other quantitative analysis techniques. The analyst must also possess the softer skills required to be able to work in a coalition environment and operate with interagency, nongovernmental, and host-nation civilians.

ORSA's career-development path must provide operational experience through rotational assignments and education in operational and strategic operations (the Advanced Operational Warfighting Intermediate Level Education Course and the School for Advanced Military Studies, for example). The ORSA must also have exposure and access to current operations to provide relevant reachback capability.

While rediscovering the combat analyst's critical role within the operational Army, FA49s cannot neglect the important role the ORSA must continue to play in the institutional Army. ORSAs perform diverse, crucial functions in recruiting and retention; promotion and selection; resource management; future force development; modeling and analysis; and wargaming. While not neglecting these missions, to be more relevant and ready, FA49 must reduce the ORSA presence in these areas (perhaps by replacing some military ORSAs with civilians) to increase ORSA's presence in the operational Army.

UEx and UEy Analytical Cells

The ORSA community provides support to operational and combatant commanders on an as-needed basis. For example, the Center of Army Analysis (CAA) has a flyaway team tailored to support a combatant commander or combined joint forces land component commander with analytical support during the preparatory phases of combat operations. The team has supported exercises in Korea, at the U.S. Army Pacific Command, at the Southern Command, and recently deployed for Operation Iraqi Freedom to serve as part of the Combined Forces Land Component Command. To support current operations, the Army has deployed analysts on an ad hoc tasking basis from within the institutional Army's analytical community. This ad hoc approach does not support an expeditionary mindset and the analyst becomes part of a pick-up team rather than being a full-fledged team member. This is about to change.

Over 10 percent of the FA49 positions in the institutional Army are moving to the operational Army—two majors to the UEx and one lieutenant

colonel and two majors to the UEy. To incorporate lessons learned from supporting the Global War on Terrorism (GWOT) with ORSA as part of the battle staffs, the Army should embed UEx and UEy analytical cells in G3 and G5 planning staffs. FA49 fully expects and intends these analytical cells to become critical assets for commanders to use across the full spectrum of operations—training, operations, logistics, manning, experimentation, resource management, and testing. This is the first step in realigning the analytical community's capabilities as a direct result of the lessons learned from operational deployments. FA49 will adjust these analytical cells to meet the operational commander's needs and further realign capabilities as joint task forces develop.

Focusing on the Analyst

The functional area's effectiveness, hence its relevance to the operational commander, depends on the ability to deliver a consistent product (the analyst). A commander's expectation of what the FA49 can accomplish cannot be based solely on the skills, education, or training of a single officer in the analytical cell. To that end, FA49 is designing the UEx and UEy analytical cells with two principles in mind: analysts work best in teams, and combat analysts must have a common toolbox of capabilities and analytical techniques, including a well-integrated reachback capability. The Army is creating a fully networked analytical capability, with cells at each UEx and UEy to serve commanders.

Teams of analysts can provide commanders with a consistent capability around the clock. Each ORSA-trained officer brings a different operational background, education (military and civilian), and interests to bear on the problems and challenges the commands face. FA49 will make the UEx and UEy nominative assignments. The recommendation for future assignments from the Officer Efficiency Report, the officer's basic branch experience, recommendations from the chain of command, and ORSA experience will help place the right officer in the right billet at the right time.

Experience teaches that the minimum number of analysts needed to provide a consistent capability is two analysts at the UEx and three at the UEy. As analysts arrive and depart, staff overlaps allow institutional knowledge to remain in the unit. Even with the capabilities of several people within these analytical cells, however, the real operational strength will come from the ORSAs' abilities to reach back to the continental United States to tap into the institutional analytical community's vast capabilities and collaborate with other operational analysts. This has proven extremely useful. ORSAs have reached back to the CAA and the G8-Force Development Directorate for actions such as the Rapid Fielding Initiative and for analytical insights into other issued equipment.

Functional Area 49 has learned that the forward-deployed analyst's most valuable asset is situational awareness; the institutional analyst's most valuable asset is time and access to knowledge. FA49 aims to improve the Army's ability to link deployed analysts with institutional analysts. FA49 envisions connecting multiple Army analytical organizations through a web portal to provide analyst connectivity worldwide. Proponents and major analytical organizations, such as the Training and Doctrine Command's Analysis Center, the CAA, and the Army Material Systems Analysis Activity, will—

- Provide training oversight before an operational assignment.
- Host conferences to bring together UEx and UEy analytical cells.
- Provide central procurement and management of the common toolbox.
- Provide an analytical clearinghouse capability (with links to the G8-Army Studies Office's database to study previous work done Armywide, for example).

ORSA Toolbox

Statistics package linked to Excel.

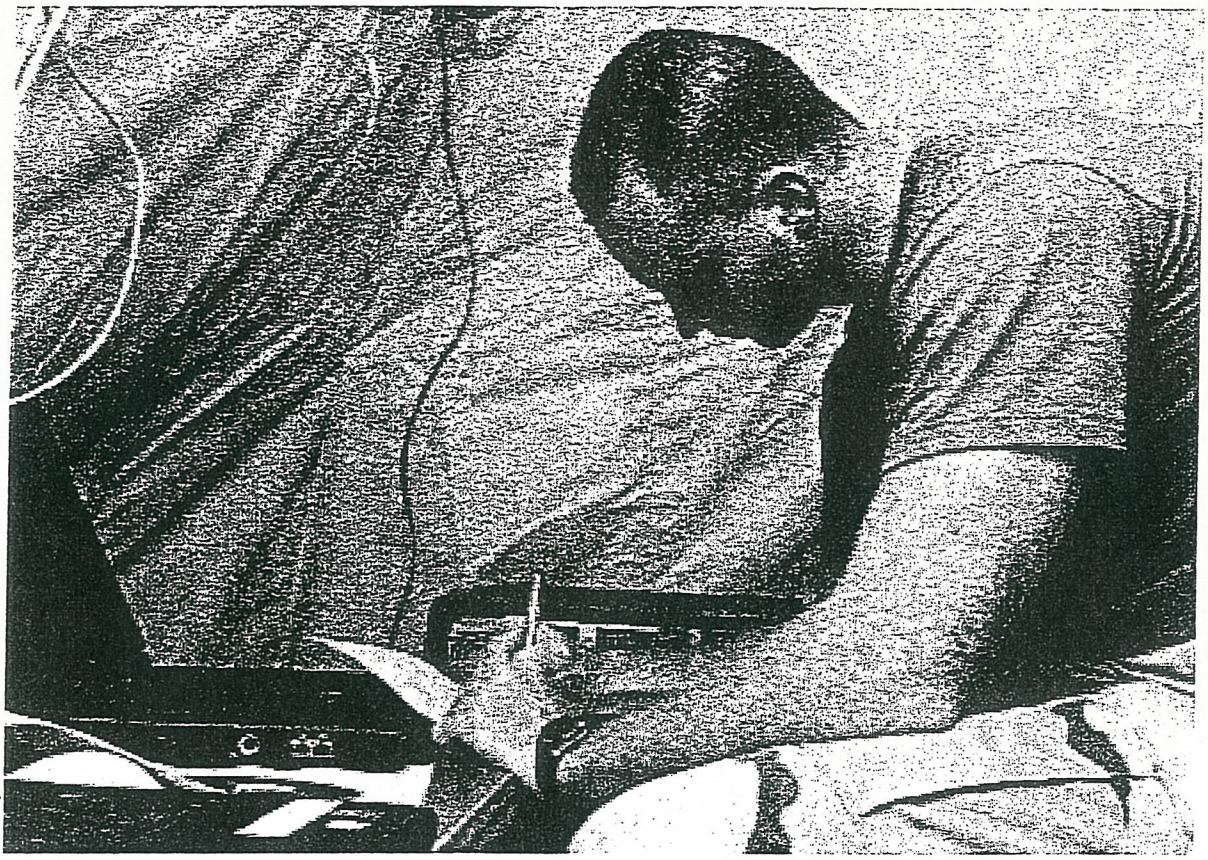
Decision software.

- Decision-tree analysis.
- Simulation (Monte Carlo and discrete-event).
- Queuing.
- Forecasting.
- Optimization (linear and nonlinear).

Blackboard software for reach back, with camera.

FalconLite Geospatial software with ArcView analytical software.

Eight-day course for all analysts heading to an operational assignment.



US Army

The Army expects to field a "blackboard" on both the classified and unclassified networks on which to post notices; disseminate information about best practices; provide on-line courses and refresher training; and solicit peer review and assistance to solve operational problems. A second-order effect will ensure the relevance of the institutional capability to accomplish classified work. Through a forward-deployed analytical cell, the CAA has successfully provided high-impact products to CJTF-7. The products could not have been replicated within theater because the unique skills to do so only resided within CAA. The effort is beginning within the Army's analytical community, but FA49 fully expects to eventually include the entire joint analytical community.

Functional Area 49 analysts must not be a drain on a command's limited resources. FA49 cannot expect each UEx and UEy to purchase and maintain the software needed to support analytical cells but must provide a complete analytical package—a trained analyst and a complete ORSA toolbox. FA49 envisions one software license for statistics, decisionmaking, mapping and geospatial analysis, and collaboration. After fielding a common set of tools, education and training should include these tools and provide subsequent education and retraining as the software and hardware evolve.

Changing the Culture

Recently, Schoomaker asked, "Are you wearing your dog tags?"[6] The purpose of the question was to address a mindset: Are you ready to deploy at a moment's notice? Until recently, the answer for the ORSA community and other functional areas within the Institutional Support Career Field was not clear.[7]

Words do matter, and most of the functional areas in the Institutional Support Career Field are integral to operational battle staffs. To that end, FA49 recommends changing the name of the Institutional Support Career Field to the Operational Battle Staff Career Field. If the name and the mindset change, the answer to Schoomaker's question would be yes.

To better align FA49 functions with the Army's core competencies, FA49 realizes that its work is not complete. Two areas that require additional emphasis are providing a joint analytical capability and growing leaders.

Functional Area 49 provides Army commanders an increased analytical capability but has not identified the corresponding solutions for the joint commander or addressed the implications of joint-capable

UExs and UEys. What is the role of the Army ORSA inside a standing joint force headquarters? How does the Army standardize the capabilities of the analytical cells inside combatant commands? Should the UEy analytical cell have an Air Force ORSA analyst embedded with it? Should the Army embed an analyst inside a Combined Air Operations Center? As the Army fields UEx and UEy capabilities, will it be in a position to experiment with different solutions to make the operational analytical capability into a joint capability? Achieving the capability is a top priority, and the Army must work closely with the Joint Forces Command, the joint staff, and the other services to do so.

The FA49 community must better understand how to grow leaders. FA49 does not have noncommissioned officers or junior officers. Entry-level positions are for senior captains and majors. The leaders the Army grows are lieutenant colonels and colonels. What exactly does leadership entail for an ORSA and what skills are required? Lessons learned from the GWOT demonstrate that leadership within the ORSA functional area is twofold: leading other analysts and leading a multidisciplinary battle staff team.

Leading other analysts requires indepth knowledge of specialized skills. An example is the major who works in the G1 at Department of the Army Headquarters as an officer strength manager who then returns as a colonel to be the division chief for the Strength, Resources, Forecasting, and Analysis Division. The Army prepares lieutenant colonels and colonels fairly well for these leadership opportunities, but the organizational construct of the ORSA cells within the institutional Army does not provide the proper balance of assignments, experience, and education for the operational analyst. ORSA colonels assigned to operational billets lead multifunctional battle staff teams.

Because these colonels lead teams that cross resource, acquisition, analysis, and force-generation functions, they must possess breadth of skills, rather than depth of skills. Currently, their training is on-the-job training, and they must rely on their education to help them with the learning curve. Reexamining the structure of courses currently in functional area stovepipes and reaching out to the other functional areas might solve this problem.

A More Ready, Relevant Force

As the Army transforms to a more ready, relevant force with a joint and expeditionary mindset, the ORSA functional area is transforming as well. It has conducted experiments with deployed commands to assess the need for combat analysts; changed its organizational construct and capabilities; and is shifting from solely supporting the institutional Army to becoming more relevant and ready for the operational Army. ORSA is developing techniques and procedures to make institutional capabilities more deployable, particularly in a virtual environment. Even with all of these changes, however, ORSA is not providing support to the full extent of its capabilities. To maximize its capabilities, ORSA must simultaneously team with the joint analytical community and the other functional areas Armywide to provide commands with a truly joint and fully staffed analytical product. ***MR***

NOTES

1. MG Rick Olson was the former Commanding General, Combined Joint Task Force (CJTF)-76, Afghanistan.
2. GEN Benjamin S. Griffin was the former commander of the 4th Infantry Division. Emphasis in original.
3. GEN Peter J. Schoomaker, "The Way Ahead: Our Army at War—Relevant and Ready," *Military Review* (March-April 2004): 2-16.
4. A unit of action (UA) is the current designation for the modular brigade organizations being formed. Units of employment (UEx and UEy) are the headquarters above brigades, roughly equivalent to a division and corps headquarters today.
5. On-line at <www.paed.army.mil/fa49/mission.htm>, accessed 12 October 2004.
6. Les Brownlee and Schoomaker, "Serving a Nation at War: A Campaign Quality Army with Joint and Expeditionary Capabilities," *Parameters* (Summer 2004).
7. This career field includes—
   - FA43—Human Resource Management (battle staff personnel specialists).
   - FA45—Comptrollers (battle staff resource specialists).
   - FA47—U.S. Military Academy professors.
   - FA49—Operations Research Systems Analysis (battle staff analysts).
   - FA50—Force Management (battle staff modernization and force flow specialists).
   - FA52—Nuclear Research and Operations (battle staff special weapons specialists).
   - FA59—Strategic Plans and Policy (battle staff planners).

Lieutenant General David F. Melcher, U.S. Army, is Deputy Chief of Staff, G8, for the Army and is the proponent for FA49 (Operations Research and Systems Analysis). He received a B.S. from the U.S. Military Academy (USMA), an M.B.A. from the Harvard Business School, an M.P.A. from Shippensburg University, and he is a graduate of the U.S. Army War College. He has served in various command and staff positions in the continental United States, the Middle East, and Germany.

Lieutenant Colonel John G. Ferrari, U.S. Army, is assigned to the Office of Management and Budget, Washington, D.C. He received a B.S. from the USMA, an M.B.A. from The Wharton School, and he is a graduate of the U.S. Army Command and General Staff College. He recently redeployed from Iraq after serving as a Strategic Analyst on the C5 (Strategy) staff of CJTF-7.

APPENDIX E

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VADM Tracey's 72nd MORSS Plenary Speech

Transcribed by Kirk Yost, MITRE, from a videotape of the presentation

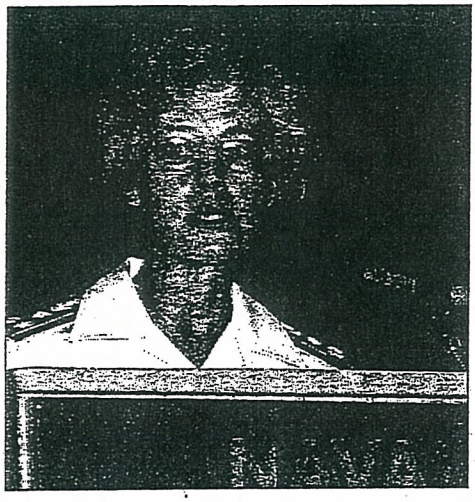
Organizing for World Class Analysis

Thank you, good morning.

Greg [Melcher] said that it was probably because we were here in Monterey that there was this very large attendance at this MORS Symposium. That's probably true; we'd probably have a harder time attracting people to Washington DC in June. But I'd also suggest it's because military operations research and analysis in general is enjoying something of a renaissance right now in our line of business.

That probably shouldn't be a surprise.

- The Internet is making ubiquitous access to data available to virtually anyone.
- Desktop computing provides access to increased computing power supporting everything from simple spreadsheet models to some fairly sophisticated simulations.
- We have an activist Secretary of Defense, who believes that senior leaders should make the most important decisions, and not just approve them. As a consequence of that, he questions every assumption, he is not influenced by tradition, he sees no Service boundaries, he has few organization lanes that he respects, and he has no tolerance for complex explanations. He makes a demand for products that will provide him analytical bases for solutions.
- And my boss, the Chief of Naval Operations, is an alumnus of the Navy's premier systems analysis organization when it was in its heyday. So, we have the people in place who are asking for analysis.
- We are on a quest for transformation. Transforming our military capabilities to meet the demands of the 21st century. That's a quest that applies to more than just systems and platforms. It applies to whole systems of structure, process, and policies. Transformation requires tradeoffs of current capabilities for future capabilities. It requires that leaders are able to prioritize, understand, and value effects, risks, and costs of the new versus the old.
- And lastly, and probably most importantly, we are at war. At war against an enemy whose strategies, tactics, techniques, and procedures continue to morph. Whose very structure and commitment to their end gives them an advantage in terms of agility and staying power.



So interest in operations analysis is on the rise, because we can do it; because the people in place making decisions are demanding it; because the questions require answers; and because the stakes have never been greater. In fact, practitioners of operations analysis and operations research find ourselves reaching back to our very roots, to the solution sets for operators in defeating the enemy.

But computing power alone and the availability of lots of data does not make for world-class analysis. And, given the nature of the outcomes that ride on the results of our analyses, we can't afford to be any less than the best in the world at what we are about.

To be world-class, we must put in place the organization, the people and the processes to do five things competently and repeatedly. The five things are these:

1. We have to understand the phenomena that underlie the effects we observe or we want to achieve. We have to find the links of causes to effects. Where they exist, we have to understand the limits due to physics, chemistry, or other laws of nature. And we have to understand how and when human behavior may introduce uncertainties or perturbations into those laws of nature.
2. We have to ensure that our models, that may be constructed to represent these phenomena, represent their essential elements accurately and well. Which ones of those elements matter? How sensitive are the results to the way we have modeled them? Can we keep evolving the methods and the tools and techniques so that we can better represent the phenomena that we are trying to model?
3. We have to understand the data sources and their validity. The Navy has now embarked on a process to build common databases so that we can stop repeatedly paying to create our own data – again – but we may not be measuring the right

(See TRACEY, p. 6)

things.. We need to put in place the processes to ensure that we understand the most revealing metrics that represent the phenomena we are trying to observe.

4. We need to understand how to interpret the results of the analysis that we do. What hypotheses were actually tested, and which ones weren't? What sensitivity analysis was done, and what wasn't? Did we use a point solution when in fact the phenomena we are modeling have variability that is predictable?
5. And we need to link analytic results to decisions. Now we do that a lot inside the Pentagon – linking analytical results or at least what passes for analysis to programming and budgeting decisions – but we need to do more than that. We need to affect the operator's decisions – we need to give him or her the tools with which to shape how we will behave on the battlefield.

I've said we need to put in place the organizations, the people, and the processes to do that. Greg [Melcher] talked a little bit about where the Navy is on its journey toward making itself a world-class analytical organization. We've started, but we have lots more work to do.

- We have identified who the lead will be on our OPNAV staff for analysis, that's the N-81, trying to restore the power of the OP-96 organization to lead the Navy in its intellectual thinking.
- We've put in place a process to do campaign analysis that begins to do some preliminary work on optimizing the location and the use of systems and feed that information inside our campaign analysis tools that evaluate the effects of those systems. But we have no relationship between that optimization work that we do and the way in which the fleet actually employs those systems.
- We have put in place a process by which we evaluate the results. But the biggest weakness in our system right now is the lack of bench strength; bench strength in the numbers of people who understand how to apply and understand analytical results. We are the Department of Defense's leading educator in operations research; we are probably the thinnest of the Services in our bench strength in terms of people who understand how to make use of analysis, how to build models, and most probably important, how to understand phenomenology.
- We have invested ourselves in doing VV&A [Verification, Validation and Accreditation] of the performance models that Greg [Melcher] mentioned; but if you look at those performance models, they are spreadsheets that capture what we will spend to achieve certain outputs. We've not done as much work on whether those are the right outputs to generate the readiness of the force we are trying to produce.

So we've started down a path that will make us better at being an analytical organization. We're a long way from being a world-class analysis organization. And I'm hopeful that, as one of the consequences of this Military Operations Research Society Symposium, we'll learn some things about what it takes to be world-class at this. We need to be world-class at more than analysis; we need to be world-class at the two operative words in your title:

1. Operations – We need to understand what works, how it works, and why it works that way. And that's everything, from why things cost what they cost, to why systems are effective or not effective in the field.
2. And Research – We are not just about supporting advocacy for systems in the programming and budgeting process. We need to invest ourselves in on-going efforts aimed at understanding fully and completely what it takes to win and how to get it.

I look forward to the results of this symposium, and I envy you the opportunity to spend a few days here in Monterey. What we are about matters much to whether we will win the global war on terror, and whether we will produce the military capability our nation needs us to produce for the 21st century. Thank you very much for your time. ✪

APPENDIX F

NAVAL POSTGRADUATE SCHOOL HONOR CODE

Academic integrity at the Naval Postgraduate School is based on a respect for individual achievement that lies at the heart of academic culture. Every faculty member and student belongs to a community of scholars where academic integrity is a fundamental commitment. Academic dishonesty is not tolerated.

Unless otherwise stated by the instructor: all in-class work submitted for a grade will be the student's own, performed without reference to materials or other individuals. Graded work assigned for completion outside the classroom allows the use of reference material, but shall be performed without the assistance of other individuals. All written work should appropriately identify referenced material.

While no single list can hope to identify and define all types of academic honor code standards, the following are cited as examples of unacceptable behavior:

Cheating. Using unauthorized notes, study aids, or information on an examination; looking at another student's paper during an examination; altering a graded work after it has been returned, then resubmitting it for regrading; allowing another person to do one's work and submitting it under one's own name.

Plagiarism. Submitting material that in part or whole is not entirely one's own work without attributing those same portions to their correct source.

Fabrication. Falsifying or inventing any information, data, or citation.

Obtaining an Unfair Advantage. Gaining access to examination materials prior to the time authorized by the instructor, unauthorized collaboration on an academic assignment; possessing, using, or circulating previously given examination materials where those materials clearly indicate that they are to be returned to the instructor at the conclusion of the examination.

Aiding and Abetting Academic Dishonesty. Providing material, information or other assistance to another with knowledge that such aid could be used in any of the unacceptable behaviors described above; failure to address observed violations of this code.

Falsification of Records and Official Documents. Altering documents affecting academic records.

d. Each student will become familiar with this Honor Code. By understanding it, the student will develop an appreciation of the reasoning behind the Code and clearly understand both the student's responsibilities and the accountability implications associated with performance of the Code. Each student is responsible for understanding the rules of a given class; if in doubt, ask the instructor.

e. Any person suspecting a violation of the honor code should address the issue with the violator and/or appropriate faculty member as soon as possible after the incident. If the faculty member determines that there is substantial evidence of a violation, the faculty member will notify his/her department/ Group Chairman. Where the evidence seems conclusive the Department Chairman will notify the Program Officer who will then notify the Associate School Dean (AD). The AD will then forward recommendation for action to the Director of Programs who will make recommendations to the Dean of Students.

6. Accountability. Violations of the Honor Code may be resolved through punitive, disciplinary, or administrative action under military or civilian systems. The full range of administrative and disciplinary actions is available to enforce the Honor Code. The appropriate action to resolve violations of the Honor Code will depend on the circumstances surrounding the incident. In the case of military personnel, these actions include informal counseling, comments in fitness reports and evaluations, disenrollment, administrative separation, and punitive measures (including punishment for violating a lawful general order, and/or conduct unbecoming an officer and a gentleman) under the Uniform Code of Military Justice. In the case of civilians, options include informal counseling, comments in performance evaluations, disenrollment, and disciplinary action including removal from the Federal Service.

7. Scope. All faculty, staff, and students will be familiar with this instruction and ensure compliance.

FRANK C. PETHO
Deputy

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